Signa LX Release 9.1 New Features Learning and Reference Guide

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Medical Device Directive

These products conform with the requirements of council directive 93/42/EEC concerning medical devices, when they bear the following CE Mark of Conformity:

CE 0459

This equipment generates, uses, and can radiate radio frequency energy. The equipment may cause radio frequency interference with other medical and non-medical devices and radio communications. To provide reasonable protection against such interference, the:

GE Signa MR/*i* Systems

comply with emissions limits for (Group 2, Class A) Medical Devices as stated in EN 60601-1-2. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment is found to cause interference (which may be determined by turning the equipment on and off), the user (or qualified service personnel) should attempt to correct the problem by one or more of the following measure(s):

- reorient or relocate the affected device(s);
- increase the separation between the equipment and the affected device;
- power the equipment from a source different from that of the affected device; and/or
- consult the point of purchase or service representative for further suggestions.

The manufacturer is not responsible for any interference caused by using interconnect cables that are not recommended or by unauthorized changes or modifications to this equipment. Unauthorized changes or modifications could void the user's authority to operate the equipment.

Do not use devices that transmit RF Signals (**cellular phones**, transceivers, or radio controlled products) in the vicinity of this equipment as they may cause performance outside the published specifications. Keep the power to these types of devices turned off when near this equipment.

The medical staff in charge of this equipment is required to instruct technicians, patients, and other people who may be around this equipment to fully comply with the above requirement.

Immunity/Emissions Exceptions: Note the exceptions from the EMC test results. Check with the business EMC engineer for this information.

In accordance with the international safety standard IEC 601-1, this system is a Class I device, acceptable for Continous Operation, having ordignary protection against ingress of water with type B applied parts and is not for use in the presence of flammable anesthetics.

CAUTION: User to call or contact the local authorities for disposal of the MR System at the end of its useful life.

Chapter 1
About This Guide

Introduction

This chapter explains the purpose and design of this Learning and Reference Guide. It is an introduction to the guide, providing information on the purpose, prerequisite skills, guide organization, chapter format, and graphic conventions that identify the visual symbols used throughout the guide.

Purpose of This Guide

This guide is written for health care professionals (namely, the MR technologist) to provide the necessary information relating to the proper operation of this system. The guide is intended to teach you the system components and features necessary to use it to its maximum potential. It is not intended to teach magnetic resonance imaging or to make any type of clinical diagnosis.

Prerequisite Skills

This guide is not intended to teach magnetic resonance imaging. It is necessary for you to have sufficient knowledge to competently perform the various diagnostic imaging procedures within your modality. This knowledge is gained through a variety of educational methods including clinical working experience, hospital based programs, and as part of many college and university Radiologic Technology programs.

Chapter Format

Each chapter contains a consistent format. This consistency provides uniformity for content delivery and a better learning environment for you. Listed below are the components for each chapter.

Introduction

The **Introduction** provides a short introduction to the chapter and a list of tasks to be presented. There are pre-questions related to the concepts and tasks of the chapter. These pre-questions help you think about the concepts and tasks as you go through a particular chapter and help reinforce the learning of the material covered.

What Do I Need to Know About...

The **What Do I Need to Know About...** section lists and explains concepts necessary to perform the tasks within the chapter.

How Do I...

The **How Do I...** section provides the detailed steps necessary to complete a given task. These detailed steps not only provide the steps to complete a task, but also provide additional information, as needed, related to a step.

On the first page of each task, there is a **Quick Steps** table in the outer margin. This **Quick Steps** table is intended to be used as a quick reference by the experienced technologist and provides only the steps necessary to complete a task.

Graphic Conventions and Legend

The format of the page is such that you have room in the outer margin to make notes as needed, except in the area where the **Quick Steps** table is located in the **How Do I...** section. Table 1-1 describes the terminology used for the various mouse functions. Table 1-2 describes the conventions used when working with menus, buttons, text boxes and keyboard keys.

Table 1-1 Conventions for Mouse Actions

Mouse Action	Description
Click	Clicking the left mouse button to select a button or icon. The button can be pressed in, not pressed in, or popped in/out.
Right-click	Clicking the right mouse button.
Middle-click	Clicking the middle mouse button.
Click and drag	Clicking and holding the left mouse button down while dragging the cursor to the desired location.
Right-click and drag	Clicking and holding the right mouse button down while dragging the cursor to the desired location.
Middle-click and drag	Clicking and holding the middle mouse button down while dragging the cursor to the desired location.
Double-click	Clicking the left mouse button twice in rapid succession.
Triple-click	Clicking the left mouse button three times in rapid succession.

Table 1-2 Conventions for Menus, Buttons, Text Boxes, and Keyboard Keys

Example	Describes
Select	Selecting an option in a check box or radial button and selecting a tab.
Press the **Enter** key	Pressing a hard key on the keyboard.
Press and hold the **Shift** key	Pressing and holding down a hard key on the keyboard.
Click **[Viewer]**	A button label or Interface button name.
Click  (Exam prior)	Selecting an icon-based button.
In the **Matrix** text box,...	The name of text box in which you can select or type text.
Type **`supine`** in the Patient Position text box (different font and bold)	Text you enter into a text box.
Select **Sort** > **Sort by date**	The pathway of selecting option(s) in a pull-down menu.

Safety Notices

The following safety notices are used to emphasize certain safety instructions. This guide uses the international symbol along with the danger, warning, or caution message. This section also describes the purpose of a Note.

DANGER: Danger is used to identify conditions or actions for which a specific hazard is known to exist which will cause severe personal injury, death, or substantial property damage if the instructions are ignored.

WARNING: Warning is used to identify conditions or actions for which a specific hazard is known to exist which may cause severe personal injury, death, or substantial property damage if the instructions are ignored.

CAUTION: Caution is used to identify conditions or actions for which a potential hazard may exist which will or can cause minor personal injury or property damage if the instructions are ignored.

NOTE: A Note provides additional information that is helpful to you. It may emphasize certain information regarding special tools or techniques, items to check before proceeding, or factors to consider about a concept or task.

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Chapter 2
New Features

Introduction

This chapter presents an overview of the Signa® LX 9.1 new and enhanced features. It contains information to complement the Signa® Infinity with Signa Select™ (ASP2) Learning and Reference Guide.

Safety Information

Please refer to the “Working Safely” chapter in Volume 1 of your Learning and Reference Guide. The Safety chapter describes safety information you and the physician must understand thoroughly before you begin to use the system. Note that you will find additional safety information throughout your Learning and Reference Guides. If you need additional training, seek assistance from qualified GE Medical personnel.

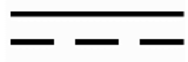
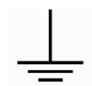
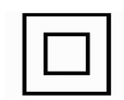
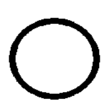
The equipment is intended for use by qualified personnel only.

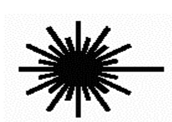
Make sure all of your Learning and Reference Guides are readily available at all times. Be sure to review the procedures and safety precautions periodically.

Product identification labels (ratings) can be found on the tops and sides of the cabinets, the rear of monitors, and other exterior surfaces on the equipment. In the event you are unable to identify these labels, contact your service personnel.

One or more of the symbols in Table 2-1 may be on your system or peripheral equipment. Please check for the labels that apply to your particular system.

Table 2-1 Safety Symbols

Symbol	Description (typical use)
	Alternating current (rating plate, terminals)
	Direct current (rating plate, terminals)
	Earth (ground terminals)
	Protective earth (ground terminals)
	Equipotentiality (terminals)
	Class II Equipment (double insulated) (ratings)
	Type B Applied Part (ratings, AP connections)
	Non-ionizing electromagnetic radiation (ratings)
	Main On (main disconnect/power switch)
	Main Off (main disconnect/power switch)
	Dangerous voltage (components, points of entry)

Symbol	Description (typical use)
	CAUTION – Dangerous voltage (barriers, points of entry)
	Emergency Stop
	Attention – consult accompanying documents
	CAUTION
	CAUTION
	DANGER
	CAUTION – Static Sensitive (ESD susceptible parts)
	Laser Radiation (laser devices)

System Maintenance

Your system requires maintenance and service intervals. Many of the maintenance checks should be performed by a qualified service engineer, some you can perform. Be aware of the required maintenance and the persons responsible for completing each requirement.

GE makes available, on request, such information as circuit diagrams and component lists to assist your technical personnel in the repair of equipment classified by GE as repairable.

WARNING: Electric shock hazard. No user serviceable parts. Refer service to qualified service personnel.

Cleaning

Background cleaning should be done by site personnel (e.g., technologists or housekeeping personnel) unless otherwise indicated in the following maintenance schedules.

Cleaning tips:

- To clean most accessories, use nothing stronger than alcohol or a mild soap and water solution.
- Use hydrogen peroxide to remove bloodstains.
- Open cell sponges are coated with canvas to allow better durability and reliability. These sponge covers allow disinfection using only 5.25% sodium hypochlorite diluted between 1:10 and 1:100 with water and 10% bleach solution. Anything else may discolor the fabric.

CAUTION: To avoid possible damage to equipment, do not use solutions containing amines, strong alkalis, esters, iodine, aromatic or chlorinated hydrocarbons, or ketones. Do not use autoclaves or the industrial washers and dryers found in most hospitals or professional laundry services.

Services

The following services in Table 2-2 should be completed at the indicated intervals and should be performed only by qualified service personnel.

Table 2-2 Qualified Service Personnel Services

Item	Period
Operator Console (OC)	
Audio Functional Check	Every 6 months
Panic Switch Functional Check	Daily
IPS	
Body Coil Power Check	Yearly
Head Coil Power Check	Yearly

Item (Continued)	Period
UPS	
UPS Check	Every 3 months
Table	
Release Assy Check and O Ring Replacement	Yearly
ID Connector Replacement	Yearly
Cradle Tape Check Replacement	Every 6 months
Cradle Emergency Release Check	Every 6 months
Table Function Check	Every 6 months
Table Appearance Check and Cleaning	Every 6 months
Table Gap Check (9 mm from bridge)	Every 6 months
Cradle Drive Belt Check	Every 6 months
Magnet Display, Covers, and Cooling Unit	
Positioning Light Check	Every 3 months
Cooling Fan, Cuff, and Hose Check	Every 3 months
Cover Appearance Check	Daily
Magnet	
Magnet Run Down Unit Battery Replacement	Every 3 years
Compressor Charcoal Absorber Replacement	Every 2 years
O^2 Monitor	
O^2 Sensor Replacement	Every 3 years
Head Coil	
O Ring Cable Replacement	Yearly
Cable and Appearance Check	Daily
Surface Coil	
Surface Coil Cable Check	Daily

Item (Continued)	Period
System	
Scan Functional Check	Every 6 months
Emergency Off Check	Every 6 months
Gating Cable Check	Daily
Top Level Test (TLT) Body Shim Test	Yearly
Eddy Current Compensation	Every 6 months
Gradient Calibration	Yearly
Image Quality Check (TLT Head SNR and T2)	Daily
Image Quality Check (TLT Body SNR and T2)	Yearly
Ghost Check	Yearly
Gapless Slice Check (Head)	Every 6 months
Gapless Slice Check (Body)	Every 6 months
System Gain Calibration (Head)	Yearly
System Gain Calibration	Yearly

You should perform the following services in Table 2-3.

Table 2-3 Operator Services

Item	Required Maintenance	Service Interval
General	Clean	4 months
	Check the table emergency release.	4 months
Patient Cradle and Pads	Check for cleanliness of pads and clean the inside of the cradle.	Daily
Patient Table	Check the table alignment and proper operation.	6 months
Coils, pads, and straps	Clean with non-abrasive cleanser. Clean coil anti-skid pads with water and mild detergent only.	Daily
Coils and coil cables	Check for defects or damage, worn cable or exposed wires.	Daily
Image Quality	Perform quality assurance and functional checks.	As recommended

Clinical Hazards

WARNING: **Do not use Projection Images for localization.**

CAUTION: **All people, patients, and others in the scan room must wear a hearing protection device, such as ear plugs.**

CAUTION: **All patients should be monitored for increased temperature during the scan acquisition. If the patient reports discomfort due to warming, stop the scan.**

CAUTION: **Make sure the patient connected intravenous (IV) lines, oxygen tubing, urinary catheters, and any other tubing and cables are long enough to allow full travel of the system and will not become entangled, pinched, or pulled.**

CAUTION: **Following the exam, your patient may need assistance when getting off the table. After lying in a prone position for a length of time, your patient may experience light-headedness upon sitting up.**

Equipment Hazards

CAUTION: **Using equipment that is damaged or has been compromised can put the patient and/or operator at risk of injury.**

CAUTION: The equipment on which the MR system application runs includes one or more hard disk drives, which may hold medical data related to patients. Such equipment may in some countries be subjected to regulations concerning the processing of personal data and the free circulation of such data. It is strongly recommended that access to patient files be protected from all persons not in medical attendance.

Indications for Use - Twin*Speed*

The Signa 1.5T Twin*Speed*™ Magnetic Resonance System is a whole body scanner designed for shorter scan times. The Signa Twin*Speed* is indicated for use as a diagnostic imaging device to produce axial, sagittal, coronal, and oblique images of the internal structures of the head or body. The images produced by this system reflect the spatial distribution of protons (hydrogen nuclei) exhibiting magnetic resonance. The NMR properties that determine the image appearance are proton density, spin-lattice relaxation time (T1), spin-spin relaxation time (T2) and flow. When interpreted by a trained physician, these images provide information that can be useful in determining a diagnosis.

Gradient, Shim, and Imaging Coils

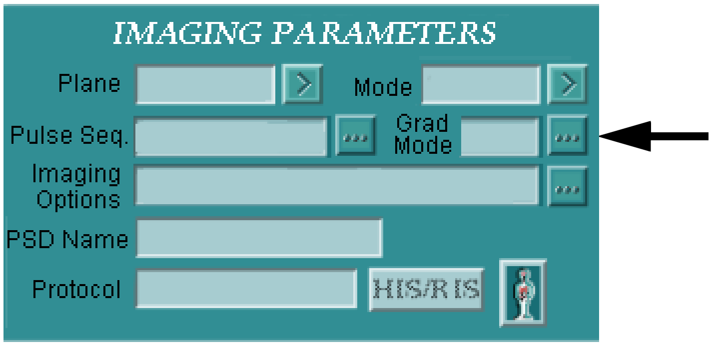
The Twin*Speed*™ Resonance Module (TRM) is 60 cm in diameter and consists of two actively shielded gradient coils. One gradient coil can be used for whole body imaging and the second for smaller optimized field of view (FOV) advanced applications.

The system is optimized to operate in two imaging modes.

- Zoom gradient mode
  - A single coil is active in a given pulse sequence
  - Intended for small FOV applications
- Whole Body gradient mode
  - A single coil is active in a given pulse sequence
  - Intended for large FOV applications

You can select the active imaging mode in between sequences during scan prescription. The **Grad Mode** text box in the Imaging Parameters area (Figure 2-1) allows you to select the appropriate imaging mode (toggles between the Zoom or Whole Body modes). You can change the mode for each specific application with the help of this text box.

Figure 2-1 Imaging Parameters Area



In addition to using the pull-down menu, you can type Whole or Zoom in the **Grad Mode** text box. The Whole Body mode defaults on.

After selection of gradient mode, the system automatically calculates the available range of echo time (TE), repetition time (TR), slice widths, and pixel sizes (FOV & matrix combinations) based on gradient specifications, thermal model of the gradient coil, specific absorption rate (SAR) models, dB/dt requirements and thermal model of the Advanced Control Gradient Driver (ACGD).

The images are annotated Z (for Zoom) and W (for Whole) after the FOV annotation.

Zoom Mode

The Zoom gradient mode is used to optimize amplitude and slew rates over smaller regions of interest. The Zoom mode has a FOV of 40x40 cm in the X and Y planes and 35 cm in the Z direction. Therefore, body parts must be well positioned within the FOV of the coil when operating in Zoom mode. The limitations of the Zoom mode are described in Table 2-4 to help ensure the Zoom gradient is used when it could improve image quality over Whole Body mode.

Table 2-4 Zoom Mode Limitations

Coils and Planes	Maximum FOV S/I	Maximum FOV A/P	Maximum FOV R/L
All coils except CTL All Planes	35	44	44
CTL Coil Sagittal and Sagittal Oblique Frequency = S/I (Not swapped)	35	44	N/A
CTL Coil Frequency = A/P (Swapped)	Choose Whole Body	Choose Whole Body	N/A

NOTE: Cardiac pulse sequences (FastCard, FGRET, SPIRAL, and FIESTA) can have up to a 44 cm FOV in all directions using the Zoom mode.

Table 2-5 identifies off-center limitations for the Zoom mode.

Table 2-5 Off-center Zoom Mode Limitations

Plane or Sequence	Off-center Limits for R/L or A/P	Off-center Limits for S/I
Axials or Coronals	12 cm	N/A
Sagittal	15 cm	N/A
Real Time Imaging	15 cm or use Whole Body	15 cm
Fluoro Trigger MRA	12 cm or use Whole Body	12 cm

Applications of the Zoom mode include:

- High end cardiac imaging
- Brain imaging
- Functional MRI (fMRI) studies
- High resolution orthopedic imaging

Due to its higher gradient amplitude and slew rate specifications, the Zoom mode is primarily used for imaging small FOVs with thin slices acquired with SE, FSE, and GRE pulse sequences. All advanced neurovascular and cardiovascular applications in Zoom mode primarily use EPI, Diffusion Weighted Imaging (DWI) EPI, Spiral, and Fast Gradient Echo (FGRE) pulse sequences.

Whole Body Mode

The Whole Body gradient mode is used to obtain the highest linearity and largest FOV (48 cm) operation. The Whole Body mode is used primarily for applications demanding large coverage along the magnet axis, or large off-center imaging (>20 cm off-center).

Applications of the Whole Body mode include:

- Spine (sagittal and coronal)
- Shoulder
- Coronal and sagittal abdomen
- Coronal and sagittal extremities

The Whole Body mode is primarily used for conventional Magnetic Resonance Imaging (MRI) sequences; Spin Echo (SE), Fast Spin Echo (FSE), Gradient Echo (GRE), and multi-shot Echo Planar Imaging (EPI).

Prescribing Images

3-Plane graphic prescription (GRx) allows you to define slices and saturation (SAT) bands while visualizing their exact locations on three different image planes simultaneously. This feature helps you achieve reductions in prescription time, as well as increase your prescription accuracy.

Refer to the Prescribing Images chapter in this guide for additional information.

Imaging Parameters

For improved imaging flexibility, existing options such as ZIP 512, Magnetization Transfer, Variable Frequency Matrix, and the Oblique scan plane are now compatible with additional pulse sequences. Table 2-6 demonstrates the compatibility between these parameters and the additional pulse sequences they can be used with.

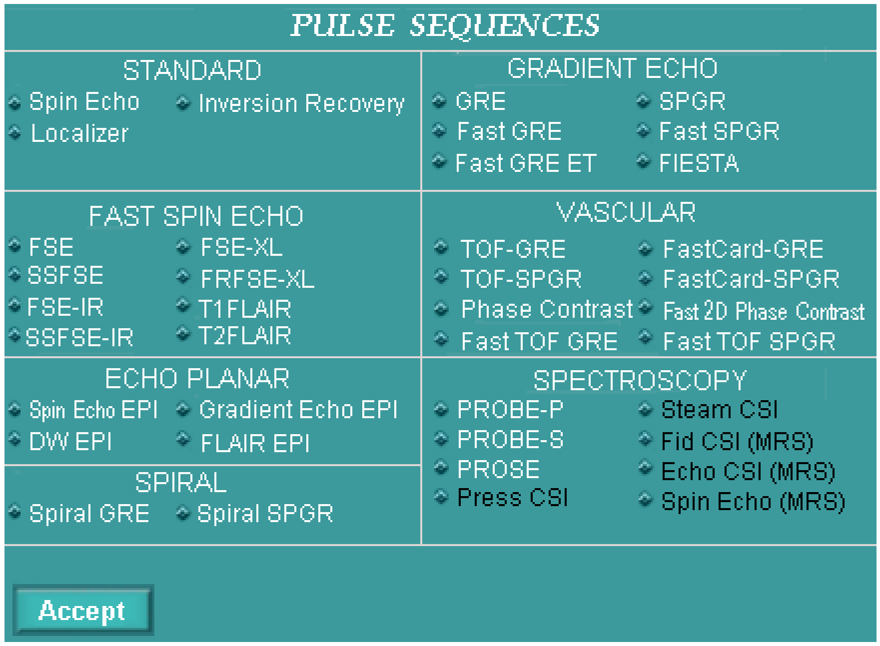
Table 2-6 Imaging Parameter Compatibility Chart

Imaging Parameters	Pulse Sequences		
	Spin Echo	2D GRE	3D GRE
Oblique Scan Plane	Yes	Yes	Yes
Variable Frequency Matrix	Yes	Yes	Yes
ZIP 512	Yes	Yes	Yes
Magnetization Transfer	Yes	Yes	Yes

The Pulse Sequence window (Figure 2-2), selected from the Imaging Parameters area, contains the following additional pulse sequences:

- FIESTA
- FRFSE-XL
- Spiral
- PROSE

Figure 2-2 Pulse Sequence Window



Fast Spin Echo Pulse Sequences

The following pulse sequences are new or contain enhancements.

- Three-dimensional Fast Spin Echo (3D FSE)
- Fluid Attenuated Inversion Recovery (FLAIR)
- T1 Fluid Attenuated Inversion Recovery (T1 FLAIR)
- Single Shot Fast Spin Echo - Excel (SSFSE-XL)
- Three-dimensional Fast Recovery Fast Spin Echo (3D FRFSE)

Refer to the Fast Spin Echo Pulse Sequences chapter in this guide for additional information.

3D FIESTA Pulse Sequence

The Fast Imaging Employing STeady-state Acquisition (FIESTA) is a fully balanced steady-state coherent imaging pulse sequence designed to produce high signal-to-noise (SNR) images at very short sequence times (TR). This guide provides you with information on the pulsing components and timing factors directly related to the 3D FIESTA imaging pulse sequence.

Refer to the 3D FIESTA Pulse Sequences chapter in this guide for additional information.

Clinical Spectroscopy Pulse Sequences

Prostate Spectroscopy Imaging Exam (PROSE) is a new 3D clinical spectroscopy sequence designed for producing spectra of the prostate area. PROSE produces multiple chemical shift spectra allowing you to examine the compounds present in the prostate area.

Refer to the PROSE Pulse Sequence chapter in this guide for additional information.

Echo Planar Imaging Pulse Sequences

There are several enhancements to the Diffusion Weighted Echo Planar Imaging (DW EPI) sequence. There is also a new addition to the Echo Planar pulse sequence family, Diffusion Tensor Imaging (DTI).

Diffusion Weighted EPI

Increased gradient strength enables DW EPI sensitivities to extend beyond the standard B-value of 1000 s/mm^2. The maximum B-value is now 7000 s/mm^2. This allows greater diffusion weighting, increasing the sensitivity of detection of non-mobile protons.

The Dual Spin Echo feature was moved from the User CV window to the Diffusion Options window. You can perform a dual-spin echo DW EPI acquisition by changing the User Control Variable (CV) 12, Dual Spin Echo Dif., from 0 (off) to 1 (on). When on, an additional refocusing pulse is applied in the diffusion sequence before the readout. This additional pulse reduces the eddy currents and minimizes image distortion; however, it increases the minimum TE by 10 to 14 ms. This option only produces a single echo.

Diffusion Tensor EPI

Diffusion Tensor Imaging (DTI) is the newest addition to the Echo Planar pulse sequence family. It is used to visualize the white matter fiber tracts in the central nervous system (CNS) and provides information on molecular diffusion of biological tissues.

Refer to the Echo Planar Imaging Pulse Sequences chapter in this guide for additional information on DTI.

Functional Magnetic Resonance Imaging

Functional Magnetic Resonance Imaging (fMRI) is an optional brain mapping software application that incorporates Blood Oxygen Level Dependent (BOLD) imaging to map task activated regions in the brain.

Refer to the Functional Magnetic Resonance Imaging chapter in this guide for additional information.

Visualize fMRI Data

BrainWave Visualizer is the visualization software included in the optional fMRI package. This software is located on your Advantage Windows (AW) 4.0 workstation. BrainWave Visualizer allows you to interactively view and edit the fMRI data.

Refer to the Visualize fMRI Data chapter in this guide for additional information.

Paradigm Development

NeuroActivator is the paradigm software included in the optional fMRI package. This software is located on the Stimulus personal computer (PC). NeuroActivator allows you to create, preview, and acquire customized paradigms that specifically meet your needs when performing brain mapping MRI studies.

Refer to the Paradigm Development chapter in this guide for additional information.

2D FIESTA Pulse Sequence

The Fast Imaging Employing STeady-state Acquisition (FIESTA) is a fully balanced steady-state coherent imaging pulse sequence designed to produce high signal-to-noise (SNR) images at very short sequence times (TR). This guide provides you with information on the pulsing components and timing factors directly related to the 2D FIESTA imaging pulse sequence.

Refer to the 2D FIESTA Pulse Sequences chapter in this guide for additional information.

Additional Cardiac Pulse Sequences

This guide explains additional cardiac sequences used in evaluating wall motion abnormalities and pathologic abnormalities within the myocardial tissue.

Refer to the Additional Cardiac Pulse Sequences chapter in this guide for additional information.

FGRET Pulse Sequences

Fast Gradient Echo-Echo Train (FGRET) is a Fast Gradient Echo (FGRE) sequence with an echo-planar (EPI) readout. Features of both the FGRE and EPI pulse sequences are combined for use in cardiac applications. This guide explains the pulsing components and timing factors directly related to the FGRET imaging pulse sequence.

Refer to the FGRET Pulse Sequences chapter in this guide for additional information.

Spiral Pulse Sequences

The Spiral pulse sequence is a 2D, Gradient Echo (GRE) or SPoiled Gradient Echo (SPGR) sequence which uses a spiral K-space trajectory to obtain the required data for image creation. This guide explains the pulsing components and timing factors directly related to the Spiral imaging pulse sequences.

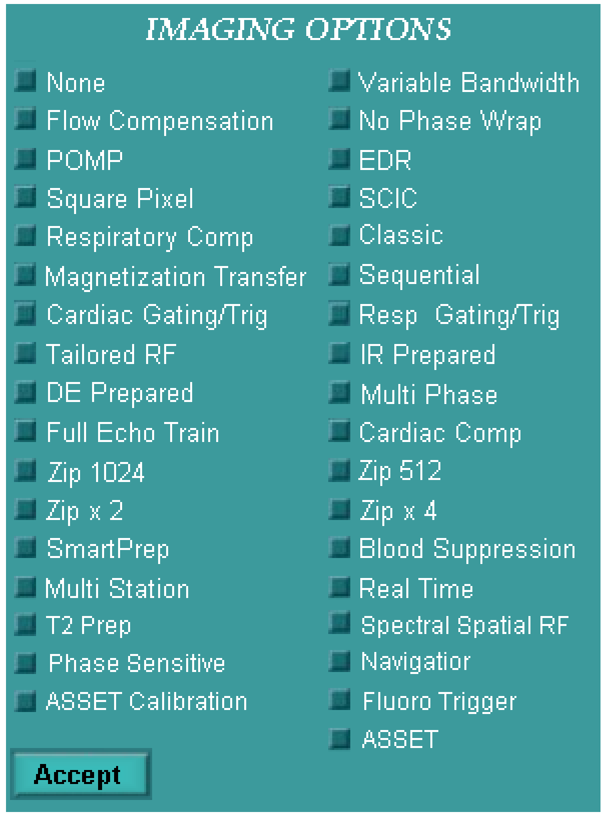
Refer to the Spiral Pulse Sequences chapter in this guide for additional information.

Imaging Options

There are several new features on the Imaging Options window (Figure 2-3).

- T2 Prep
- Spectral Spatial RF
- Navigator
- Fluoro Trigger
- ASSET Calibration
- ASSET

Figure 2-3 Imaging Options Window



T2 Prep

T2 Prep is an option available with Spiral imaging. It can be used to suppress tissue and decrease signal from various structures.

Refer to the Spiral Pulse Sequences chapter in this for information on T2 Prep.

Spectral Spatial RF

Spectral Spatial RF (SSRF) is an imaging option used to suppress signal from fat during Spiral sequences and suppresses fat and water when used with PROSE pulse sequences.

Refer to the Spiral Pulse Sequences and Clinical Spectroscopy Pulse Sequences chapters in this guide for information on SSRF.

Navigator

Navigator is a cardiac option that enables you to perform navigated, free-breathing, coronary artery acquisitions. The Navigator Imaging Option is used with a 3D enhanced Fast Gradient Echo (GRE) pulse sequence to acquire the images.

Refer to the Cardiac Navigator chapter in this guide for information on the Navigator option.

Fluoro Trigger

Fluoro Trigger is an option available for Fluoro Triggered Magnetic Resonance Angiography (FT MRA) imaging. This option must be used in order to perform a FT MRA sequence.

Refer to the Bolus Triggering chapter in this guide for information on Fluoro Trigger.

ASSET and ASSET Calibration

Array Spatial Sensitivity Encoding Technique (ASSET) is an option that enables faster scanning when using the Torso Phased Array (PA) coil. It is designed to achieve shorter breath-held acquisitions, thus making it easier for your patients experiencing difficulty holding their breath for long periods of time.

ASSET Calibration is an option used along with the ASSET option that allows you to calibrate your scan data prior to performing an ASSET imaging acquisition.

Refer to the Imaging with ASSET chapter in this guide for information on ASSET and ASSET Calibration.

Bolus Triggering

FT MRA is a technique that uses a thick slab, two-dimensional (2D) real time acquisition and reconstruction to monitor the region of interest for contrast bolus.

Refer to the Bolus Triggering chapter in this guide for additional information.

Bolus Chasing

SmartStep has been improved to include:

- Capability of saving a site customized protocol
- Automatic prescanning of all saved series
- A quiet delay period after the bolus has been detected
- A delay count-down timer after the bolus has been detected
- Four K-space filling options
- Easier selection of mask and venous series
- Meta-series can be copied and pasted
- Left mouse clicks only are used to activate all scan functions, including AutoStep

Refer to the Bolus Chasing chapter in this guide for additional information.

Real Time Imaging

*i*Drive™ Pro Plus is an optional software package that provides you with a flexible environment for using real time imaging. This guide explains how to image real time with *i*Drive Pro Plus. It provides key concepts regarding the acquisition, tools, and image review options available.

Refer to the Real Time Imaging chapter in this guide for additional information.

Displaying Images

Reference Image

Several changes have occurred within the Reference Image Viewer feature. The following is a list of things you can do to a referenced image:

- Window/Level (all methods)
- Image selection buttons (Image +/-)
- Zoom
- Display Normal
- Flip/Rotate
- Pan
- Scroll

When you click the **[Image]** button on the Film Composer icon on the Film Composer Options window, both the Reference image and the Primary image appear within a film format cell. Note the size relationship between the Primary and the Reference images is not indicative of what the images will look like when the film is printed. The Reference image is larger than it appears on the film.

All Reference image viewports display the same image. You can no longer put unique images within separate or different viewports. If you change the image within one Reference image viewport, all other Reference image viewports update to the same image, even if you have isolated the Reference image viewport through a double-click.

If you have the Reference images displayed in all of the viewports and use the F4 (Film Series) feature, references images are printed. If a Reference image is not on all viewports, no reference images are printed.

User Preferences

There have been additions and changes to the Partial Annotation and Tick Mark features located on the User Preferences window.

Partial Annotation

Two annotation fields have been added to the Partial Annotation selection accessed from the User Preferences window.

- Date of Birth, which is located in the upper right corner of the viewport.
- Slice Thickness and Slice Spacing, which were added to the lower left corner of the viewport.

Tick Marks

The Tick Mark selections from the User Preferences window have changed to Vertical or Horizontal, rather than Shown or Hidden.

Browser Sort Feature

The sort function in the Browser menu bar allows two sorting methods for Series:

- Sort by PPS status (Complete or Defer)
- Sort by Series number

Managing Images

The MOD automatically detaches if there is no archive activity for 60 minutes. This feature is designed to minimize the potential for MOD corruption if the system is shutdown without performing a detach. When the system detaches the MOD, the message "MOD Detached" appears in the archive status area.

The MOD automatically re-attaches in the following situations:

- If you have auto archive active, the system automatically re-attaches the MOD as soon as images appear in the archive queue.
- If Archive Pause is active, then an attach is automatically performed when the **[Resume]** button is clicked from the archive queue window.
- If you are manually archiving, an attach is automatically performed when an exam, series, or image is saved.

Functool

The PROSE sequence can be displayed through Functool 2, located on your Browser. PROSE sequences are displayed in the same manner as 3D Focal Brain spectroscopy sequences.

Refer to the Spectroscopy Functool 2 chapter in this guide for additional information.

ASSET

Array Spatial Sensitivity Encoding Technique (ASSET) is an imaging feature that allows faster scanning when using the Torso PA coil. It is designed to achieve shorter breath-held acquisitions, thus making it easier for your patients experiencing difficulty holding their breath for long periods of time.

Refer to the Imaging with ASSET chapter in this guide for additional information.

Accelerator Commands

There are several changes in the naming conventions of the Accelerator Commands. Table 2-7 lists the updated Accelerator Commands along with their type-in abbreviation and description.

Table 2-7 Accelerator Commands

Command	Type-in Abbreviation	Description
Image Manipulation		
Flip horizontal	ftb	Flips the image horizontally (top to bottom).
Flip vertical	flr	Flips the image vertically (left to right).
Format	fo	Sets the display format to a maximum of five rows and five columns. For example, **`fo 3 5`**.
Reset	rs	Resets the initial display parameters.
Zoom	zo	Sets the magnification factor. For example, **`zo 2`**.
Invert	inv	Inverts the video.
Scroll	scroll	Moves the image in the viewport as you click and drag the mouse.
Screen Save	scnsave	Captures the selected images exactly as it is displayed and creates a new image of series number 99 on the system disk that includes all graphics and display factors applied to the image and/or viewport at the time of capture.
Graphics		
Report cursor	rc	Creates a report cursor graphic.
Report pixel	rp	Displays a 4x4 mm cursor that can be dragged to a new location. When the cursor is deposited, the mean, standard deviation, and area are displayed.
Angle	ang	Creates an angle type measurement cursor.
Ellipse	el	Creates an ellipse type measurement cursor.
Rectangle	rect	Creates a rectangular type measurement cursor.

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Chapter 3

Prescribing Images

Introduction

3-Plane graphic prescription (GRx) allows you to define slices and saturation (SAT) bands while visualizing their exact locations on three different image planes simultaneously. This feature helps you achieve reductions in prescription time, as well as increase your prescription accuracy.

This chapter explains the process of prescribing images. It provides the concepts necessary to graphically prescribe image locations, the tracker location, and SAT bands, as well as the basic steps to apply these techniques. It contains the step-by-step instructions to help you learn how to:

- Prescribe 2D graphic locations
  - Single and multi-group locations
  - Radial locations
- Prescribe 3D graphic locations
  - Single and multi-slab locations
  - Tracker location
- Prescribe SAT locations

In addition, this chapter answers the following questions:

1. What are the advantages of 3-Plane GRx?
2. What scan planes can I prescribe in 3-Plane GRx?
3. What types of prescriptions can I prescribe in 3-Plane GRx?
4. What imaging mode allows me to prescribe a tracker?
5. How many SAT bands can I prescribe at one time?

What Do I Need to Know About...

This section presents the concepts necessary to successfully complete the process of prescribing images. Specifically, you need to understand:

- 3-Plane GRx Basics
  - Acquiring Valid Localizers
  - Defining the Scanning Range
  - Localizer Viewports
  - Selecting Images
- Two-dimensional Prescription
  - Multi-group Prescription
  - Radial Prescription
- Three-dimensional Prescription
  - Multi-slab Prescription
  - Tracker Prescription
- SAT prescription
- 3-Plane GRx functions
  - Report Cursor
  - Zoom
  - Display Normal
  - Window Width and Level
  - Pan
  - Reference Lines
  - Copy Rx
  - Reset Center

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3-Plane GRx Basics

3-Plane GRx allows you to define slices and SAT bands while visualizing their exact locations on three different image planes simultaneously. This feature is facilitated by using one image (acquired from a 3-Plane localizer) from each plane in conjunction with another during graphic prescription. It allows you to graphically prescribe on any of the images from the localizing series. It also gives you the flexibility of manipulating slice location and placement on any one of the three images interactively, while observing the resultant changes in the prescription in the other two planes. 3-Plane GRx helps you achieve reductions in prescription time, as well as increase your prescription accuracy.

During 3-Plane GRx, you can:

- Use the List Select window to load a series of images into the viewports
- Create different slice groups (parallel, oblique, radial, 2D, 3D, Tracker, and SAT)
- Move, size, and rotate the prescription not only on the viewport in which you deposited the prescription, but also the other two viewports
- Increase or decrease the number of slices or slabs
- Operate on the different slice groups (edit, delete, rotate, or resize)
- View graphic slice locations and SAT bands together in all viewports
- View and edit some application parameters based on the prescription and pulse sequence you select
- Save a 3-Plane GRx prescription as protocol

3-Plane GRx is available with all scan planes, although the behavior it exhibits may differ depending on the scan plane prescribed. Table 3-1 lists the action taken by 3-Plane GRx with each scan plane.

Table 3-1 Scan Plane and 3-Plane GRx Behavior

Scan Plane	Action in 3-Plane GRx
Axial	Only axial slices shall be prescribed. No rotation is allowed.
Sagittal	Only sagittal slices shall be prescribed. No rotation is allowed.
Coronal	Only coronal slices shall be prescribed. No rotation is allowed.
Oblique	No restrictions on prescribed slices. Rotation is allowed in all intersections shown.

3-Plane GRx allows you to prescribe the following types of prescriptions:

- Two-dimensional (2D)
  - Radial
  - Multi-group
  - SAT
- Three-dimensional (3D)
  - Tracker
  - Multi-slab
  - SAT

The 3-Plane GRx can be manipulated in either the 2D or 3D GRx mode and also in the SAT mode. 3-Plane GRx is viewable and editable in the SAT mode, and the SAT bands are viewable and editable in the GRx mode. However, new SAT bands cannot be created on the GRx screen and new GRx groups cannot be deposited on the SAT screen.

The 3-Plane GRx and the Tracker prescription display together in the Tracker mode and you are able to manipulate the tracker as well as the GRx volume. The tracker is only displayed on the image to which it is prescribed.

Upon completion of a 2D, 3D, or SAT prescription, the 3-Plane GRx data is translated into right, anterior, and superior (RAS) coordinates, these values are passed on to scan, and the geometry calculations are completed and updated.

Acquiring Valid Localizers

The **Graphic Rx** icon (Figure 3-1) is available in the Additional Parameters area when you are defining a series prescription.

Figure 3-1 Graphic Rx Icon

3-Plane GRx can be used after an axial, sagittal, coronal, oblique, or 3-Plane scan has been completed. A valid localizer has the same patient entry, patient position, and landmark as the current prescription. The valid localizers for 2D and 3D mode for each plane are given in Table 3-2.

Table 3-2 Valid Localizers for 2D and 3D Modes

Current Prescription Plane	Valid Localizer
Axial	Sagittal, Coronal
Sagittal	Axial, Coronal
Coronal	Axial, Sagittal
Oblique	Axial, Sagittal, Coronal, Oblique

Valid localizers for SAT prescriptions for each plane are given in Table 3-3.

Table 3-3 Valid Localizers for SAT Prescriptions

Current SAT Band	Valid Localizer
Axial	Sagittal, Coronal, Axial
Sagittal	Axial, Coronal, Sagittal
Coronal	Axial, Sagittal, Coronal
Oblique	Axial, Sagittal, Coronal, Oblique

Defining the Scanning Range

When defining the scanning range in 3-Plane GRx, there are some prescription limitations you need to consider. Table 3-4 provides you with the limitations of 3-Plane GRx prescriptions.

Table 3-4 Prescription Limitations

Prescription	Limitations
3-Plane GRx	A maximum of 256 slices can be prescribed.
3-Plane SAT	A maximum of 6 SAT bands can be prescribed.
3-Plane Tracker	A maximum of 1Tracker prescription can be deposited.

3-Plane GRx allows you to change the following Scanning Range parameters as per the mode selected in Table 3-5. The corresponding changes display in all three viewports.

Table 3-5 Editable Scanning Range Parameters

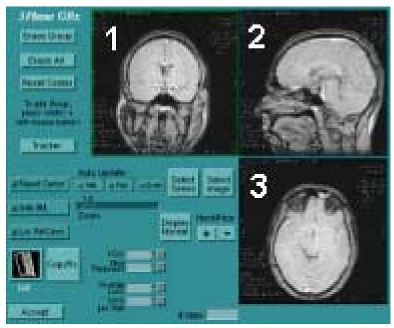
Mode	Scanning Range Parameters
2D	FOV, Spacing, Slice Thickness, Frequency Direction, and Phase FOV
3D	FOV, Slice Thickness, Overlap Locations, Number of Locations per Slab, and Phase FOV

The Scanning Range area updates after you accept the prescription. You cannot edit the parameters once a prescription is present and you close 3-Plane GRx. You are only able to see and modify the graphic prescription previously made by re-entering the **Graphic Rx** icon in the Additional Parameters area.

Localizer Viewports

When you open 3-Plane GRx, a busy cursor appears on the screen until initialization is complete and the appropriate three localizer images display. 3-Plane GRx has three 410x410 localizer viewports (Figure 3-2).

Figure 3-2 3-Plane GRx Viewports



The localizer images can be images from a 3-Plane Localizer or, if another series is used, three images of the same plane display. A prescription can be made on any of the three localizer images. The intersections of the slices prescribed are shown on the other viewports. For example, if a graphic prescription is made on the Viewport1 localizer image, the slice intersections are shown on Viewport2 and Viewport3 localizer images. The intersections signify the area on the localizer image that will be scanned.

There are various scenarios 3-Plane GRx uses for determining which localizer images are displayed as default images in the three viewports. The default load is the last valid 3-Plane Localizer.

- If you are opening 3-Plane GRx for the first time, the middle image of the coronal set of the most recent series of the 3-Plane Localizer loads in the first viewport. The middle image of the sagittal set loads in Viewport2 and the middle image of the axial set loads in Viewport3.
  - If the localizer series is not a 3-Plane Localizer, the last compatible series scanned is divided into thirds and loads in the viewports, displaying the center slices of each third.
- If you are entering 3-Plane GRx for the second time and have acquired a 3-Plane Localizer, the system displays this series.
  - If this localizer series is not a 3-Plane Localizer, the valid localized series for the set prescription displays.

- If you had previously prescribed SAT bands, then the default images are the localizers that were used in the SAT prescription.

At any instant of time one of the three viewports is always highlighted. The active viewport is highlighted with a green or bright border. There are various graphic tools that can be applied either to a selected viewport or to all the viewports. The following tools operate on the images loaded into the viewports:

- Window and Level (W/L) – using the center mouse button
- Pan – using the right mouse button
- Zoom – using the slider
- Report cursor – using the toggle button

When communication with the Graphic server is lost and the system does not respond to any of your actions on the 3-Plane GRx screen for an amount of time, an error message posts (Figure 3-3) and the 3-Plane GRx window closes. You are able to re-enter 3-Plane GRx by clicking the **Graphic Rx** icon again, retaining all of your deposited prescriptions.

Figure 3-3 Communication Error Message Box

Selecting Images

The List Select window allows you to select a series other than the default localized series for the scan. When you click the **[Select Series]** or **[Select Image]** buttons (Figure 3-4), the List Select Series (Figure 3-5) or the List Select Image window opens in the bottom corner of the 3-Plane GRx screen.

Figure 3-4 Select Series and Image Buttons

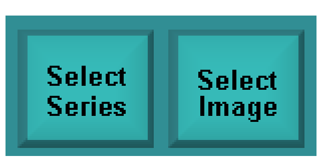
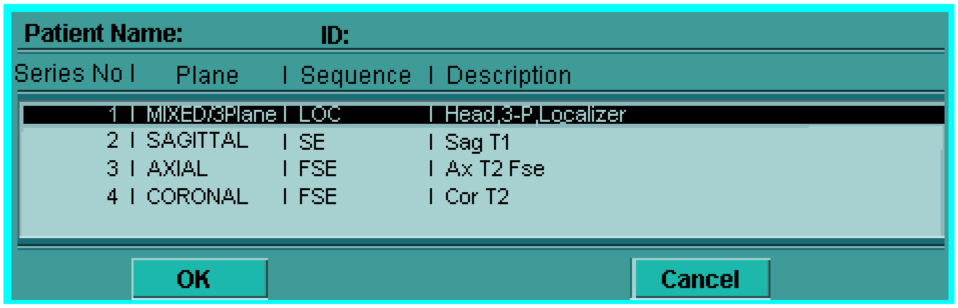


Figure 3-5 List Select Series Window



The List Select window provides a filtered list of series that fit to the current patient, with same study and same location.

You can only select the same series for all viewports. Then you are able to select an individual viewport and put a specific image in that viewport from the selected series. Loading a specific localizer image on any of the three viewports can be accomplished by clicking the **[Select Series]** button to choose the desired series and the **[Select Image]** button to load the selected localizer image.

You are able to select any series from the list. For any series other than a 3-Plane Localizer, the middle image of the selected series loads in the second viewport and images on either end of the same series load in viewports one and three. For example, if there are 9 images in the currently selected series, then image 2, 5, and 8 are loaded in the viewports.

The select series button is disabled when there is a prescription on any of the viewports. When you click the **[Erase All]** button or when there are no prescriptions on the viewport, the **[Select Series]** button is enabled again.

The **[Select Image]** button displays all the images of the current series. The image shown in the currently highlighted viewport is highlighted in the list of images. You are able to select any image from the list and that image loads in the currently highlighted viewport.

You are also able to switch between images in a valid localizer image set using the **[+]** (Next) or **[-]** (Prior) buttons. The Next button moves to the next image of the currently selected series for the active viewport. The Prior button moves to the previous image of the currently selected series for the active viewport.

Two-Dimensional Prescription

Upon clicking the **Graphic Rx** icon in a 2D prescription, the 3-Plane GRx screen opens and displays with the default images in the viewports (Figure 3-6).

Figure 3-6 3-Plane GRx Screen for a 2D Prescription

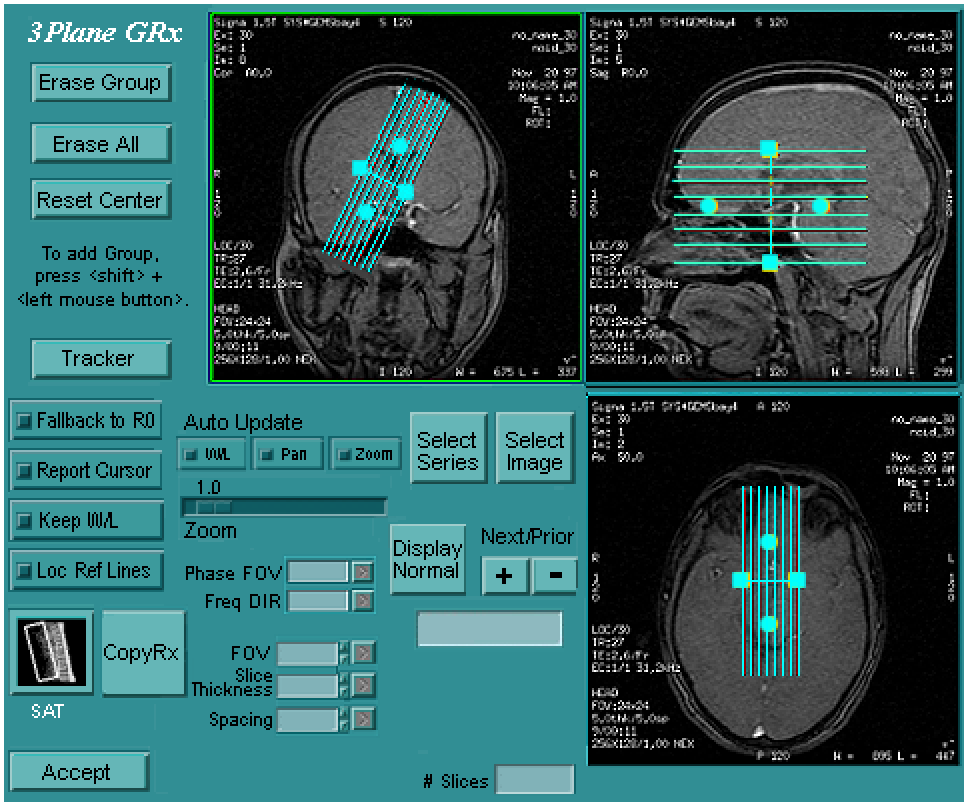


Table 3-6 provides a description and acceptable values for each selection on the 3-Plane GRx screen for 2D prescriptions.

Table 3-6 3-Plane GRx Selections and Descriptions for 2D Prescriptions

Selection	Description
[Erase Group]	Erases a particular group of slices or slabs and its corresponding intersections.
[Erase All]	Erases all the prescriptions and its intersections. Only enabled when there are prescriptions present.
[Reset Center]	Allows you to page through a data set and reselect a new center image for prescription. The new center is based on the image in the active viewport.
Instructions for Add Group	Adds a group of slices in a different location.
Fallback to R0	Moves the slice centers from off center prescribed position to isocenter in the slice select direction of the localizer image.
Report Cursor	Provides a report of the cursor location on each of the three viewports.

Selection	Description (Continued)
Keep W/L	Keeps the selected W/L for the active viewport. The W/L remains at the Keep W/L values as the [+] and [-] buttons are used to view other images within the selected viewport. If Keep W/L is not on, then as the [+] and [-] buttons are used to view other images within the selected viewport, the W/L reverts to the auto W/L values.
Loc Ref Lines	Allows you to view the reference lines on all viewports. The lines represent the location of the other two graphic planes. For example, the lines on the sagittal localizer image represent the locations of the axial and coronal localizer images.
SAT icon	Opens the SAT screen. The currently prescribed slices are automatically accepted.
[Copy Rx]	Copies a previous Rx with the same FOV, slice thickness, and spacing. The slices are copied onto the image used to originally prescribe them. You may single-click on the desired series and click **[Accept]** or double-click to display the locations.
[Accept]	Registers slice prescription and exits Graphic Rx.
Viewport1	Displays the middle slice of the first third of the most recent series which could be used as a localizer. Displays the middle coronal image if a 3-Plane Localizer was acquired.
Viewport2	Displays the middle slice of the most recent series which could be used as a localizer. Displays the middle sagittal image if a 3-Plane Localizer was acquired.
Viewport3	Displays the middle slice of the last third of the most recent series which could be used as a localizer. Displays the middle axial image if a 3-Plane Localizer was acquired.
Auto Update: W/L	Enables the W/L function to apply on all viewports.
Auto Update: Pan	Enables the pan function to apply on all viewports.
Auto Update: Zoom	Enables the Zoom function to apply on all viewports.
Zoom	Adjusts magnification factor for displayed images using the slider.
[Select Series]	Lists valid series from which a localizer image can be selected.
[Select Image]	Lists the images for the selected series.

Selection	Description (Continued)
[Display Normal]	Returns the displayed image to its default size and location. In other words, it removes the pan and zoom factors.
[-] [+] (Prior/Next)	Displays the previous or next image in the series from the currently displayed image.
Text Box	Allows you to enter the image number for the image you wish to display.
Phase FOV	Allows you to shorten the scan time by scaling down the FOV size in the phase direction. The pulse sequence determines the range and increment values.
Freq DIR	Defines the scanning direction associated with the frequency encoding gradient. In general, frequency is the long axis of the imaging plane. The default frequency direction is automatically entered, but you can swap frequency and phase directions by changing the entry from the predefined list.
FOV	Defines the area of the anatomy selected for imaging. The size is indicated in centimeters.
Slice Thickness	Assigns thickness of each slice location in millimeters.
Spacing	Assigns space between the slices.
# Slices	Reports the number of slices prescribed. A value is automatically entered in this text box if slice thickness, slice spacing, and the start and end locations are specified. You cannot manually enter a value.

The length of the Slice lines in a 2D graphic prescription represent the FOV coverage. The graphic objects on the Slice lines in 3-Plane GRx enable you to define where and how to acquire the slices.

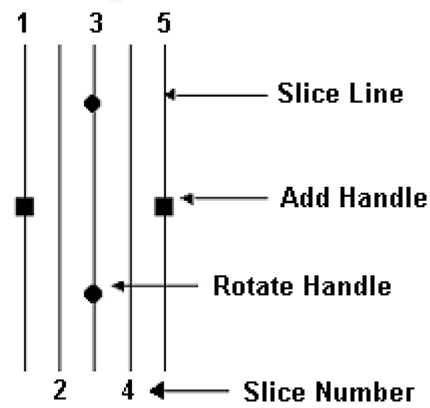
The graphic objects have handles for rotating, adding, or removing slices based on the prescription restrictions. You can move and rotate the prescription in progress not only in the viewport in which you deposited the locations, but also in the other two viewports.

The graphic objects provide the following functionality:

- The Add handle gives you the ability to increase or decrease the number of slices.
- The Rotate handles appear at the center of the slice group (one above and one below the center of the slice) for oblique prescriptions to give you the ability to turn the slice prescriptions.
- The Slice lines allow movement of the prescription by clicking and dragging on any area of the slice line other than the handles, to adjust the position of the entire graphic prescription.

The selected graphic objects in the active viewport appear blue and the unselected graphic objects appear yellow. The graphic objects of a 2D prescription are shown in Figure 3-7.

Figure 3-7 2D Graphic Objects



As you add or delete slices, the slice numbers appear or disappear accordingly.

NOTE: If your system has a black and white monitor, the graphic objects appear white and the active group displays the graphic handles.

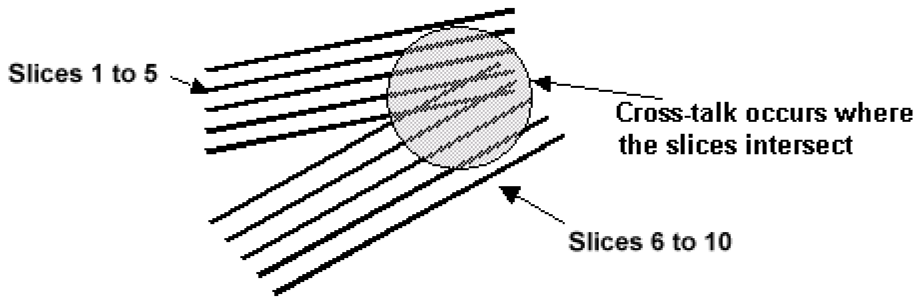
Multi-Group Prescription

It is possible to prescribe multiple groups of slice locations, each with a unique tilt angle within the same acquisition, on all GE Signa® MRI systems. This capability is referred to as Multi-slice, Multi-angle, or MSMA. MSMA is available for any 2D Fast Spin Echo (FSE), Spin Echo (SE), and multi-planar Gradient Echo (GRE) sequences. This is useful when an entire range of slice locations is not desired or needed for a given anatomical body part (e.g., axial spine and sagittal TMJ examinations).

Note that dark banding artifacts, commonly known as cross-talk, and low SNR tissue contrast changes are likely to occur when MSMA slices intersect. The data for multiple groups are generally acquired in an interleaved slice acquisition order. For example, two groups of five slice locations are prescribed and the slices intersect one another. The first group contains image numbers 1 to 5; the second group, 6 to 10. Interleaved slice acquisition order results in the image data being gathered as slices 1/3/5/7 and 9 gathered first, then the system goes back and collects data for 2/4/6/8/ and 10. Collecting the data in this manner results in cross-talk where the groups intersect (Figure 3-8). Care should be taken to avoid overlapping groups on top of the anatomy of interest.

NOTE: Sequential GRE and sequential Fast GRE/SPGR sequences do not exhibit this cross-talk because the slices are acquired one at a time.

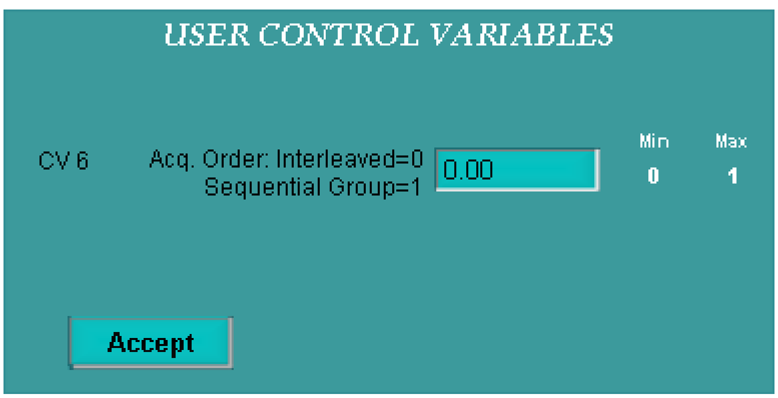
Figure 3-8 MSMA and Cross-talk



Multi-slice Multi-group (MSMG) means only the slices within an angled group are acquired within a single acquisition. Three angled groups of slices therefore results in three separate acquisitions. Cross-talk artifacts are not seen with MSMG.

When using a Fast Spin Echo (FSE) pulse sequence, a user control variable (CV) becomes available with the prescription, allowing you to choose between MSMA and MSMG. Figure 3-9 illustrates the acquisition order options of choosing an interleaved or a sequential group for the current acquisition.

Figure 3-9 User CVs Screen for a Multi-Group Prescription



You must define the acquisition order by selecting an Interleaved Acquisition or a Sequential Group. Selecting Sequential Group (1) results in a MSMA acquisition and selecting Interleaved (0) results in a MSMG acquisition. Interleaved is the default selection.

MSMA means all prescribed slices are acquired within a single acquisition and MSMG means all data is collected for the slices in one group before the system goes on to the next group to start a new acquisition. During a MSMG acquisition, there is a time interval of one TR period from the end of one group acquisition to the start of the next group. This allows spins to return to a state of equilibrium, thus reducing the possibility of cross-talk.

With MSMA and MSMG prescriptions, the color for the selected group and its corresponding intersections is blue and a yellow color represents the unselected group and its corresponding intersections. The intersections display on all the three viewports for all the groups present.

When prescribing MSMA or MSMG acquisitions, the group with the largest number of slices controls the frequency and phase direction. For example, if you are prescribing axial slices through the disc spaces on a Lumbar (L) spine examination, you may prescribe three slices through L3-4 and L4-5 that have a small angle. Then you may prescribe five, very steep angled slices through the L5-S1 disc space. The steep angle, passing 45°, makes the slices an obliqued-coronal and the frequency direction changes to S/I.

You may only perform the move, rotate, or add slices operations on one group at a time. Any changes within a group reflect in the corresponding displayed intersections. One group is always in the selected state. You are able to erase a single group after selecting the group and clicking the **[Erase Group]** button.

As you add or delete the slices in a multi-group prescription, the slice numbers appear or disappear accordingly with the slices shown. The numbers are contiguous across multiple groups.

NOTE: When using MSMA acquisitions, if two slices or groups of slices are 90° to each other, one of the groups of the resulting images will be rotated. The R/L, A/P, and S/I annotations on the images are correct.

Radial Prescription

Radial prescriptions can be prescribed graphically with 3-Plane GRx. This allows multiple slices to be acquired around a central axis in the same series. Radial and partial radial graphic prescription is available with FSE-XL, FRFSE-XL, Single Shot Fast Spin Echo (SSFSE), SSFSE-Inversion Recovery (IR), FastCard, FastCINE, and 2D FIESTA pulse sequences. This type of prescription can be useful for imaging, but not limited to, knees, Magnetic Resonance Cholangiopancreatographies (MRCPs), myelograms, and hearts.

When you are prescribing a radial sequence with 3-Plane GRx the GRx screen appears with several additional selections, as seen in Figure 3-10 and defined in Table 3-7.

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Figure 3-10 3-Plane GRx Screen for Radial Prescription

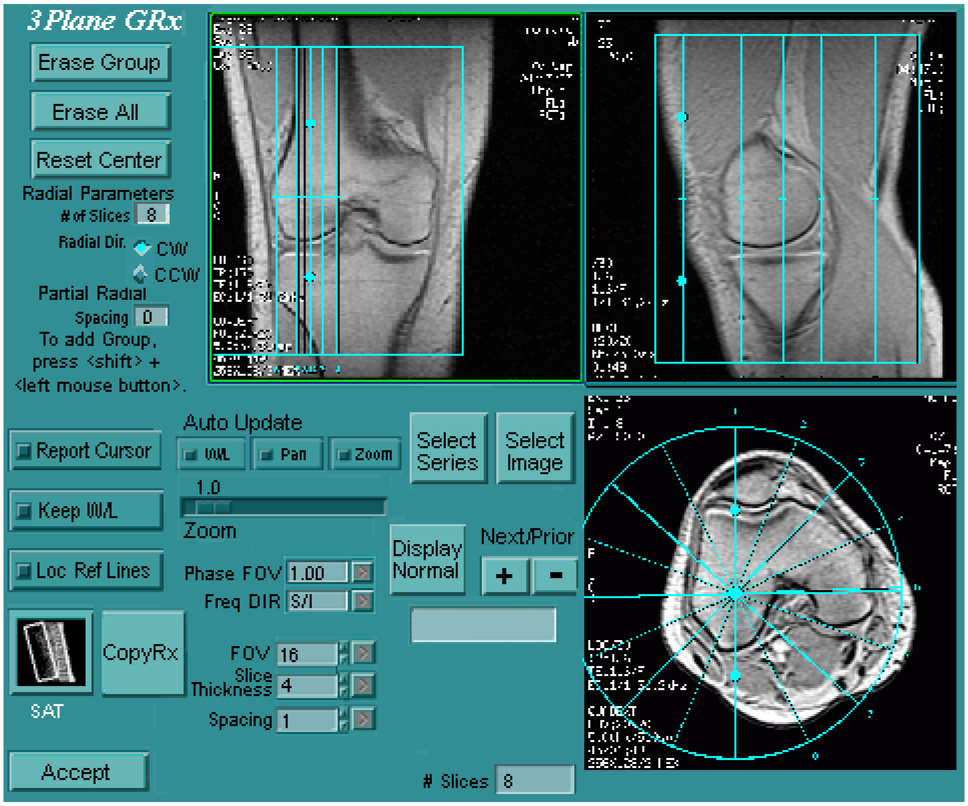


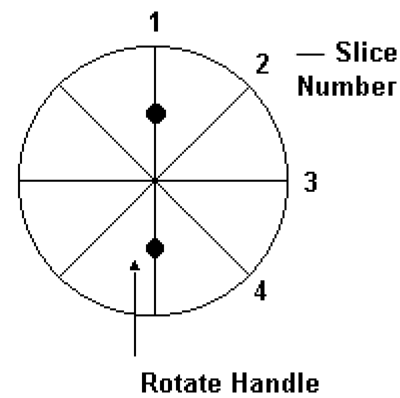
Table 3-7 3-Plane GRx Selections and Descriptions for Radial Prescription

Selection	Description
# of Slices	The number of slices prescribed for a radial graphic prescription. The maximum allowable is 36. Keep the number of slices at the default of one if you do not desire to perform a radial prescription.
Radial Dir.	Clockwise and counter clockwise directions for radial prescription. System defaults to clockwise.
Spacing	Controls the angle between slice locations by defining the degree of space between each slice.

For radial prescriptions, you must define the number of slices and the radial direction while prescribing the acquisition. You have to explicitly type the number of slices in the **# of Slices** text box. The intersections accordingly display the number of slices in the three viewports. You can enter a different number of slices to dynamically change an active prescription.

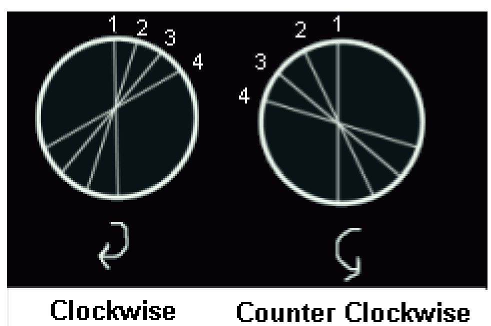
The radial prescription has Rotate handles to turn the prescription and the slice numbers are displayed as in Figure 3-11. You are also able to move and rotate the intersections of the radial prescriptions. The intersections of the radial prescriptions display as blue bounding boxes (Figure 3-10). You are not able to graphically change the number of slices in a radial prescription.

Figure 3-11 Radial Graphic Objects



The radial direction can be clockwise or counterclockwise as shown in Figure 3-12. The system defaults to one slice and clockwise rotation. These settings can be changed.

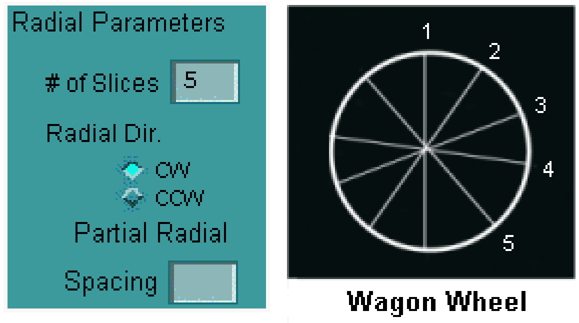
Figure 3-12 Radial Directions



The maximum number of slices in a single group is determined by the selected pulse sequence. The largest number of slices that can be prescribed per group is 36 locations. If this limit is exceeded, the system does not accept the value. To continue, you must enter a new value with a lower number of slices.

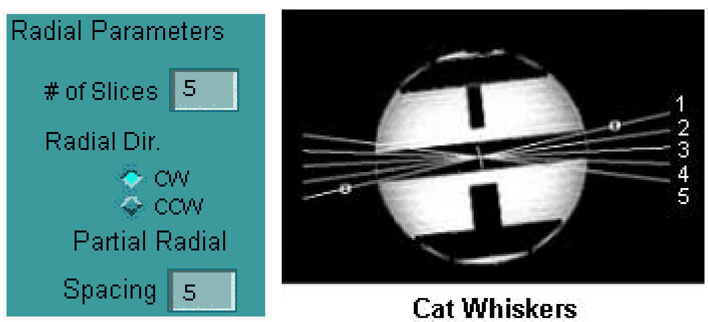
The **# of Slices** and **Spacing** text boxes control the angle between the slices of the radial prescription. For example, if you select 5 slices in the Radial Parameters area and leave the **Partial Radial Spacing** text box empty, your graphic prescription looks like a wagon wheel with a 36° angle between each slice (Figure 3-13).

Figure 3-13 Wagon Wheel Radial Prescription



If you select 5 slices in the Radial Parameters area and 5° of spacing in the Partial Radial area, your graphic prescription looks more like cat whiskers (Figure 3-14) and there are 5° between each slice location.

Figure 3-14 Cat Whiskers Radial Prescription



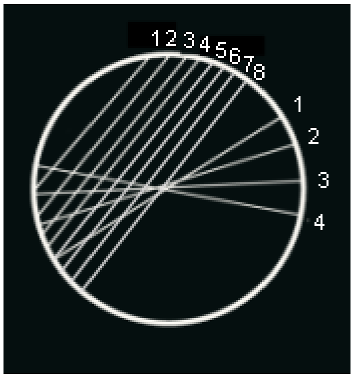
You may also prescribe multiple radial groups. Once you have deposited the first graphic prescription group, pressing the **Shift** key and clicking on the image allows you to deposit the second group. The new, active radial graphic displays blue and the inactive, first group turns yellow. Changing the number of slices parameter changes the number of slices in the active (blue) group.

If you are prescribing a FSE-XL radial sequence and the slice ordering is interleaved (acquires the maximum number of slices per acquisition,) your images may exhibit cross-talk and you do not have the option of choosing the number of locations before pause. Selecting Sequential slice ordering on the User CVs screen changes the number of slices to equal the number of acquisitions with no slice cross-talk.

After accepting a graphic prescription, you need to enter the number of locations before pause in the Acquisition Timing area. The number of locations before pause can be of a confusing nature. If you select zero, you do not have to push the scan button for every slice (angle), but you may have cross talk problems. If you select one, you control the scan, so you could let the tissue relax by waiting a few seconds before clicking the **[Scan]** button.

Since each slice is an angle and each angle is a group, the maximum number of locations before pause is always one unless you prescribe an oblique group on the same series. For example, if you prescribe a radial scan with 4 slices and an oblique group with 8 slices, you could enter 8 in the **# of Locs Before Pause** text box. You would start the scan, the system would acquire those 8 slices, then you would hit scan four more times (one for each slice) to acquire the radial. The oblique slices in the group (single angle) would let you select 4 (or whatever number of locations before pause). See the example in Figure 3-15.

Figure 3-15 Multi-group Oblique and Radial Prescription



In addition, there are several factors you should consider when setting the locations before pause in radial prescriptions:

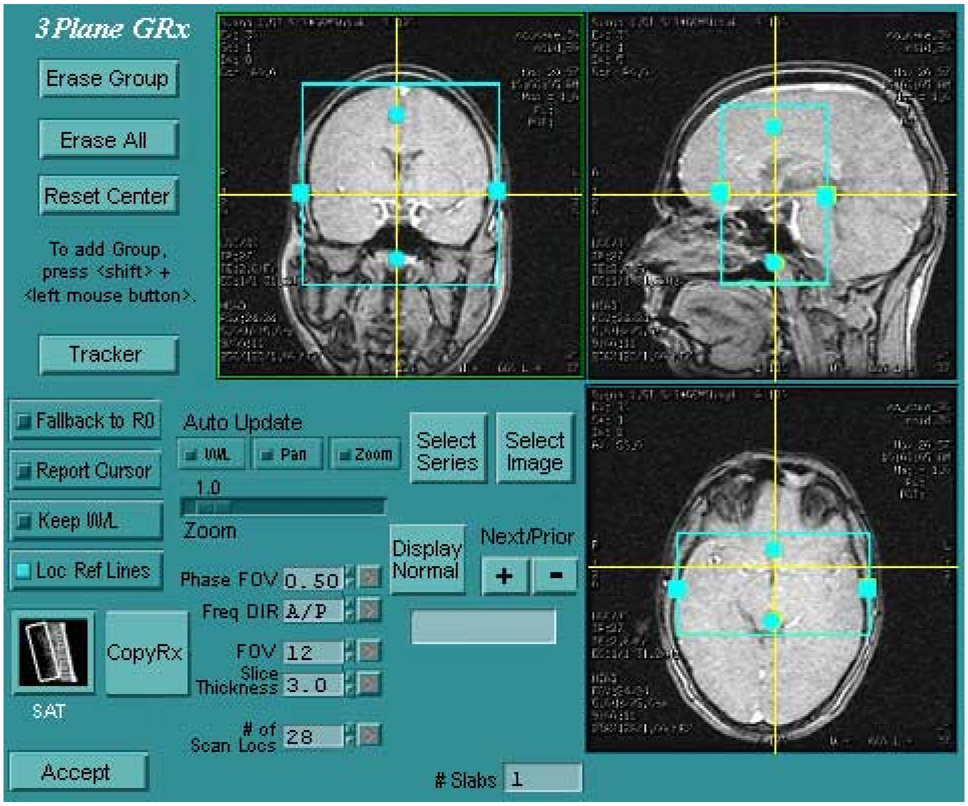
- Set the number of locations before pause to zero if all slices are the same angle. This allows you to scan all slices in one breath hold. For multiple shorter breath holds, type in any number to break up the group.
- Set the number of locations before pause to zero or one for a radial prescription. If you select one, the system pauses after each slice and you need to click the **[Scan]** button for each slice. Although zero is compatible, it causes cross-talk where the slices intersect.
- Set the locations before pause to the number of slices of the largest group when using MSMA. This enables you to scan one group or one angle at a time.

Three-Dimensional Prescription

3-Plane GRx is also available in a 3D mode, as shown in Figure 3-16. The 3D mode excites an entire scan volume or slab with a wide RF pulse. Images acquired in 3D mode are spatially encoded in the phase, frequency, and slice axes.

Note the Localized Reference Lines (yellow or bright) are turned on in the 3D prescription in Figure 3-16. This is not automatic, you must click the **[Loc Ref Lines]** button to enable the feature.

Figure 3-16 3-Plane GRx Screen for 3D Prescriptions



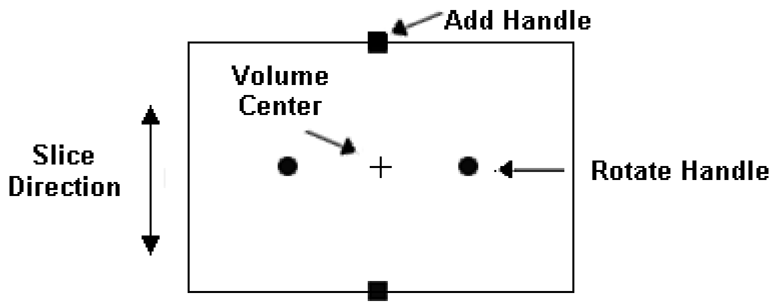
In addition to most of the selections on the 2D 3-Plane GRx screen, the following selections in Figure 3-8 are available on the 3-Plane GRx screen for 3D prescriptions.

Table 3-8 3-Plane GRx Selections and Descriptions for 3D Prescriptions

Selection	Description
[Tracker]	Defines the tracker slice location and thickness in a SmartPrep™ acquisition. (Only available with 3D Gradient Echo (GRE), Spoiled Gradient Echo (SPGR) or Time of Flight (TOF) pulse sequences.
# of Scan Locs	Defines the number of scan locations to be acquired in a single slab prescription.
Overlap Locs	Assigns the number of overlap locations (slices) per slab in a multi-slab prescription. (Only available with 3D GRE, SPGR, and TOF.
# of Scan Locs	Defines the number of locations to be acquired per slab in multi-slab prescriptions.
# Slabs	Reports the number of slabs prescribed for a multi-slab acquisition.

In 3D prescription, the box displayed (Figure 3-17) represents the size of the imaging volume based on FOV, slice thickness, and number of scan locations selected in the scanning range. A selected 3D graphic object in the active viewport appears blue, while the unselected graphic objects appear yellow.

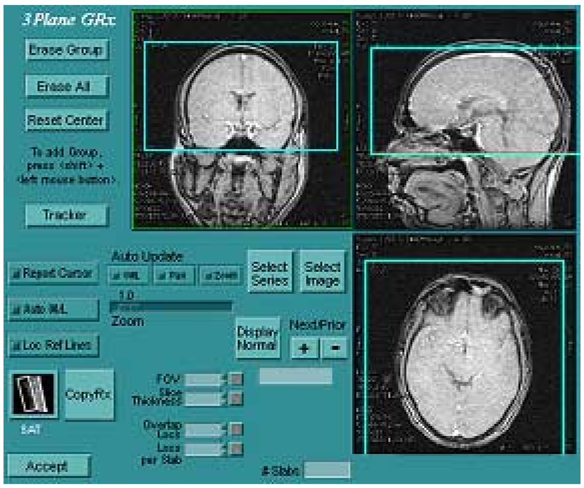
Figure 3-17 3D Graphic Objects



Oblique 3D has the same operation on the graphic slabs as in the 2D oblique mode. The Rotate handle and Add handle for slice prescription are available along with a tic mark indicating the center of the volume.

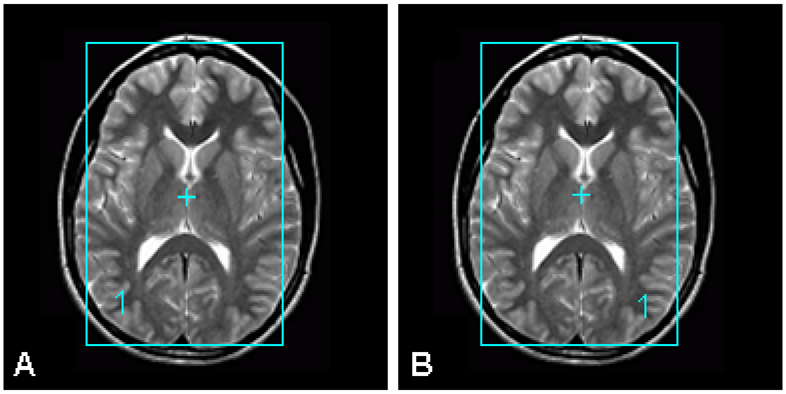
When the slice range extends to the center of the reference line, the FOV size is displayed on the localizer scan plane that is the same as the prescribed plane. The graphic box can be picked up by the edges and moved. This is a useful tool to verify the anatomy is not outside the phase FOV and if it is, then you can move the FOV accordingly. Figure 3-18 is an example of a 3D axial prescription. Note the FOV box displayed on the axial image. The box does not appear for 2D oblique prescriptions.

Figure 3-18 3D Axial Prescription



The 3D slice direction is displayed by the “1” and “+” which are displayed in the volume. The side to which the “1” is closest is the side of the volume that begins with the slice one.

Figure 3-19 Slice Ordering



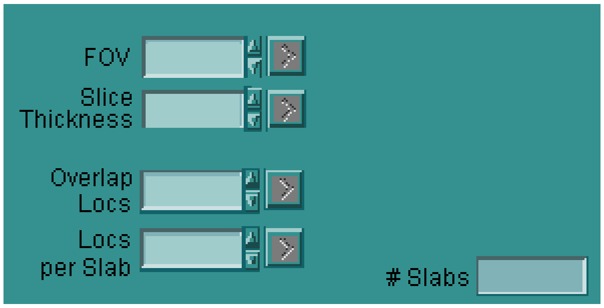
Prescription A displays the “1” to the left of the “+” indicating the images will be acquired left to right. Prescription B displays the “1” to the right of the “+” indicating the images will be acquired right to left.

Multi-Slab Prescription

3D Multi-slab acquires multiple, overlapping image volumes, and combines overlapping locations from two adjacent slabs. The active slab and its intersections appear blue and an unselected slab appears yellow, along with its corresponding intersections.

The multi-slab editable text boxes in 3D 3-Plane GRx are shown in Figure 3-20.

Figure 3-20 3D Multi-Slab Text Boxes

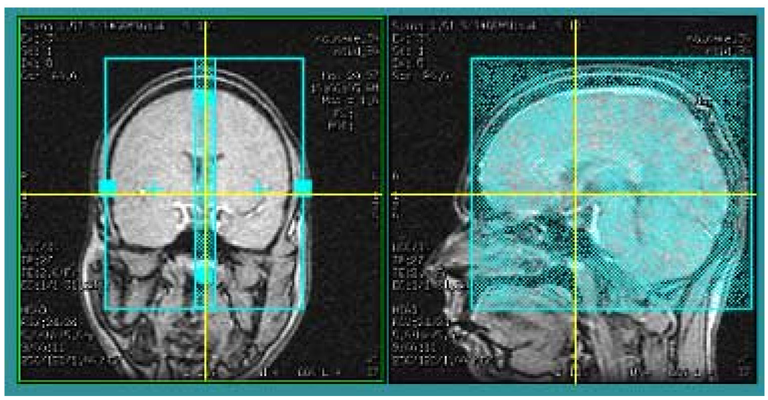


The purpose of the overlap is to have a prescription of slabs with overlaps that result in a continuous series of slices — with no gaps. Remember, any 3D acquisition has aliased image data on both ends of the slab, which is discarded. If this aliased (and discarded) image data is in the overlap area, the scan prescription should result in a continuous — no gap, set of slices.

With 3D multi-slab TOF acquisitions, if no overlap is prescribed between adjacent slabs, a substantial inter-slab boundary artifact (venetian blind) is created due to the decrease in blood-background signal to noise. An overlap of 25% is recommended, with uniform flip angle excitations, to minimize the artifact.

When the overlap locations are positioned over the center reference line, the slices perpendicular to the prescribed plane display the graphic volume with a grid like appearance (Figure 3-21).

Figure 3-21 3D Multi-Slab Overlap



The shading in Figure 3-21 is to help you visualize anatomy that is overlapped on a multi-slab prescription. Note the grid like appearance of the slab on the sagittal image. This is due to the overlap area being placed over the sagittal reference line on the coronal localizer image. If you move the overlap area away from the sagittal reference line and the slab on the sagittal loses the grid like appearance.

Tracker Prescription

In 3-Plane GRx, you are able to deposit a Tracker prescription for 3D Fast TOF or 3D Fast GRE pulse sequences. The Tracker Rx screen (Figure 3-22) is accessed by clicking the **[Tracker]** button on the 3D 3-Plane GRx screen. You are only able to view and manipulate the tracker on the image which you initially deposit it.

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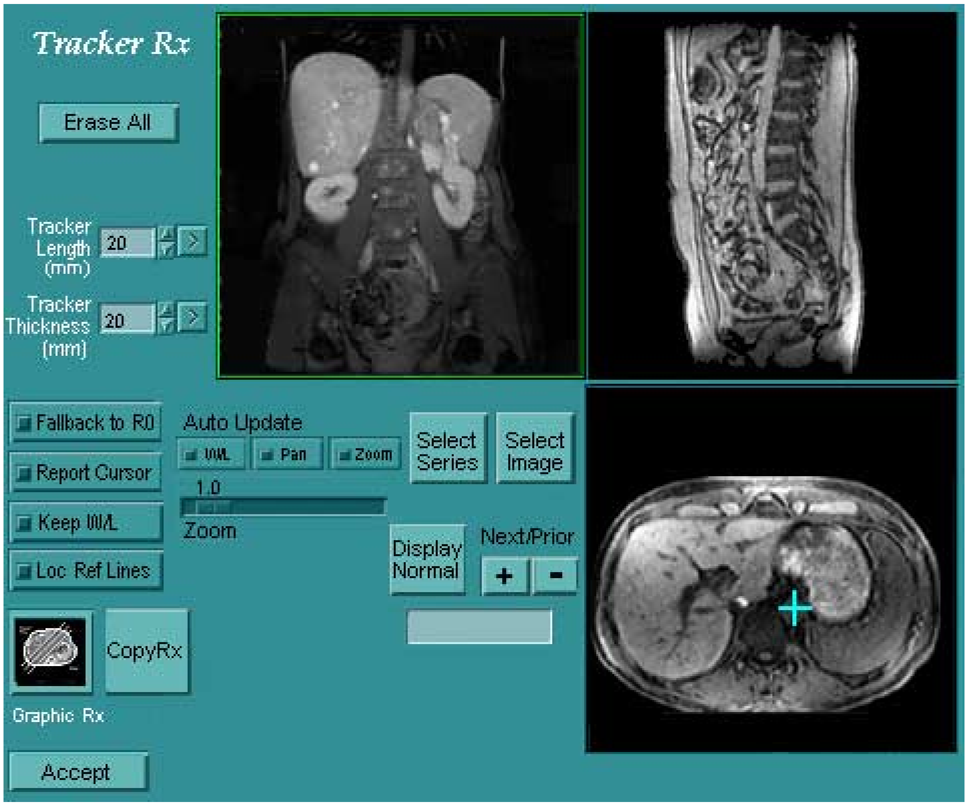
Figure 3-22 3-Plane GRx Screen for a Tracker Prescription



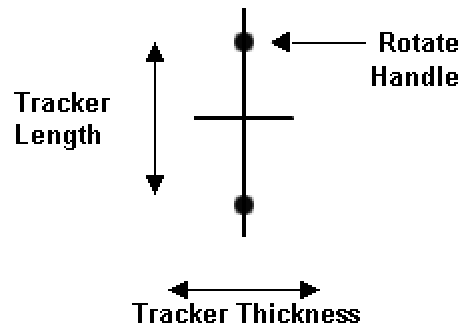
In addition to several of the selections available on the 3D 3-Plane GRx screen, Table 3-9 lists the other selections and their descriptions that become available when prescribing your tracker volume.

Table 3-9 3-Plane GRx Selections and Descriptions for Tracker Prescription

Selection	Description
Tracker Length (mm)	Defines the length of the tracker in millimeters.
Tracker Thickness (mm)	Defines the thickness of the tracker in millimeters.
[Accept]	Accepts the Tracker prescription and brings you back to the 3-Plane GRx screen.

The Tracker prescription, as shown in Figure 3-23, has two Rotate handles. One handle is above the prescription and one is below the prescription. The middle cross hair represents the thickness of the tracker and the length is represented by the size of the line.

Figure 3-23 Tracker Graphic Objects



You can use the Rotate handles to turn the Tracker prescription to angle with your vessel of interest. You can move the location of the Tracker prescription by clicking the prescription and dragging it.

The length of the Tracker prescription can be adjusted by entering a value in the **Tracker Length (mm)** text box in millimeters or by selecting the value from the drop down list provided. You can also change the thickness of the Tracker prescription by entering a value or selecting the value from the drop down list in the **Tracker Thickness (mm)** text box.

SAT Prescriptions

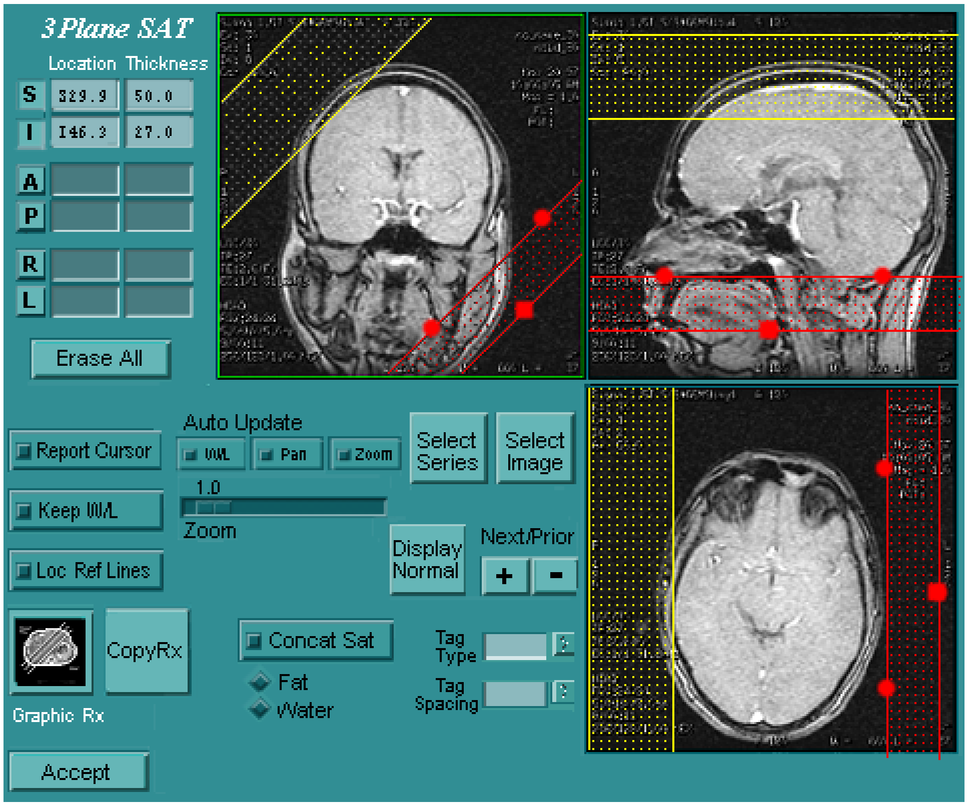
You can graphically prescribe SAT pulses on a localizer image from a valid series within the current exam. A valid series is any prospective orthogonal or oblique series with the same landmark.

The SAT icon in the Additional Parameters area (Figure 3-24) becomes available after you acquire a valid series and if the series you are prescribing supports SAT bands.

Figure 3-24 SAT Additional Parameter

Upon clicking the **SAT** icon, the 3-Plane SAT screen (Figure 3-25) opens and displays with the default images in the viewports. Alternatively, you can access the SAT mode by clicking the **SAT** icon on the 3-Plane GRx screen.

Figure 3-25 3-Plane SAT Screen



In addition to the selections on the 3-Plane GRx screen, Table 3-10 provides you with the selections that become available on the 3-Plane SAT screen.

Table 3-10 Selections Unique to the 3-Plane SAT Screen and Descriptions

Selection	Description
S, I, A, P, L, R	Defines a SAT pulse in the direction of the selected plane.
Location	Defines the location of the leading edge of the SAT pulse. Leave this text box blank for default positioning of SAT outside FOV or adjacent to the first or last slice. A positive or negative numerical value is entered here to explicitly prescribe the SAT location.
Thickness	Defines the thickness/width of the SAT band. The default thickness is defined by the PSD and in most cases is 80 mm. Enter a value from 10 to 200 in steps of 1.
Graphic Rx icon	Opens the 3-Plane GRx screen. The currently prescribed saturation bands are automatically accepted.

Selection	Description (Continued)
[Copy Rx]	Copies SAT prescriptions for a previously prescribed series to current series. All SAT selections must be deselected to use copy Rx. Select the desired series and click the **[Accept]** button or double-click the series. The SAT bands copy to and appear on the currently displayed images.
[Concat SAT]	Enables "walking SAT" for slice-select direction SAT pulses in concatenated acquisitions. Only valid with orthogonal images, parallel slices, and multi-acquisitions.
Fat	Suppresses fat using spectral or chemical saturation pulses. Center Frequency must be set to Water.
Water	To suppress water using spectral or chemical saturation pulses. Center Frequency must be set to FAT.
Tag Type	Allows selection of stripe or grid spatial SAT tags to obtain cardiac images sensitive to tissue motion. Only available with FastCINE GRE pulse sequences.
Tag Spacing	Sets the distance of pixel spacing between the tag bands.
[Accept]	Registers SAT prescription and exits 3-Plane SAT.

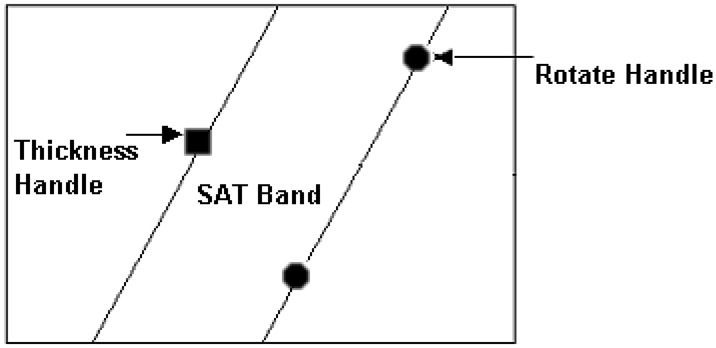
Clicking the directional buttons (S, I, A, P, R, L) allow you to prescribe SAT bands on any of the 3 localizer images. You are able to drop up to six SAT bands at one time. The intersections of the SAT bands display on the other 2 viewports.

The SAT bands display as rectangular dotted areas representing thickness and location. The SAT localizer images can be changed to prescribe SAT bands on various planes. You are able to move, size, and rotate the SAT bands on all the three viewports. A selected SAT band appears red and an unselected SAT band is yellow.

NOTE: If your system has a black and white monitor, the SAT bands appear white and the active band displays the handles.

There are two Rotate handles on the leading edge of the SAT band, one on each side of the center of the SAT band. A Thickness handle for changing the width of the band is also provided. You can change the bands location by clicking anywhere on it, except for the handles, and dragging it. These objects are shown in Figure 3-26.

Figure 3-26 SAT Objects



Not all six SAT bands are visible on one viewport. Table 3-11 provides the SAT bands you can see on the different planes of localized images.

Table 3-11 Visible SAT Bands for Localizers

SAT Bands	Localizer Plane
A, P, R, L	Axial
S, I, A, P	Sagittal
S, I, R, L	Coronal
S, I, A, P, R, L	Oblique

You are able to drop all six bands on different localizers based on the validity of the SAT bands for that localizer. For example, you may drop S and I bands on the sagittal localizer, A and P bands on the axial localizer, and R and L bands on the coronal localizer. The intersections for all of the bands display on the other viewports.

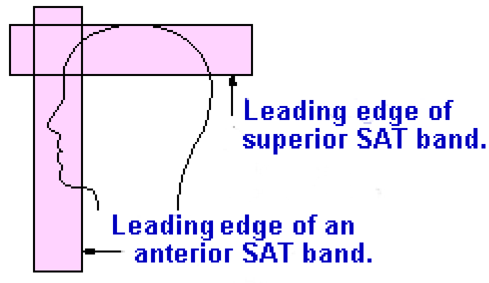
Once you deposit the band, you cannot drop the same type of band again in any of the other viewports. For example, if you drop an S band on the sagittal localizer, you cannot drop an S band again in any of the other localizers.

You can change the thickness of any band you deposit by dragging the Thickness handle provided on the SAT band or by explicitly typing the thickness value in the **Thickness** text box provided in the SAT screen. The change in the thickness of one SAT band changes the thickness in its corresponding intersections also.

The SAT pulse default location and thickness value change based on the pulse sequence selected. Generally, the thickness for Spatial SAT pulses default to 80 mm in all directions if a complimentary band does not currently exist. A complimentary band is a band opposite the selected band. For example, and inferior SAT band is complimentary to a superior SAT band. If a complimentary band exists, then the thickness of the band equals the thickness of the complimentary pair band. Default location for most Spatial SAT pulses are 30 mm away from the last slice, abutting the FOV in phase and frequency directions.

SAT bands may be prescribed inside or outside the scanning volume. SAT locations entered state the leading edge of the SAT pulse as shown in Figure 3-27.

Figure 3-27 SAT Band Leading Edges



The **SAT** icon, located in the Additional Parameters area, updates after you accept the prescription. It indicates the SAT pulses applied within the current series. For example, Figure 3-28 indicates the series prescription includes fat SAT, as well as an S and I SAT band.

Figure 3-28 SAT Icon with Applied Pulses

The icon only indicates if SAT has been turned on at its default value or if the SAT pulse location/thickness has been altered. It does not indicate the actual thickness or location. To view the thickness and location of SAT pulses, enter the SAT screen. Several examples of the **SAT** icon labels are listed below.

- Spatial SAT pulses applied at the default location and thickness are shown in upper case letters beneath the **SAT** icon, e.g., S, I.
- Spatial SAT pulses applied with a change to their thickness or location are shown in lower case letters, e.g., s. i.
- If Fat or Water suppression has been selected, the selection is indicated as FAT or WATER.
- If no SAT selections are made, the icon label reads, "SAT".

Disabling the direction button (S, I, A, P, R, L) deletes the corresponding band and its intersections from all the viewports. For example, if you click the **[S]** direction button and then click the sagittal localizer, an S band copies to the sagittal and coronal localizers. If you again click the **[S]** direction button (disabling), the S band that was copied to the sagittal and coronal localizers erases.

3-Plane Graphic Functions

There are various graphic functions that can be performed on a selected viewport or all three of the viewports. You can individually selected a viewport by clicking in that viewport. When a viewport is individually selected, it has a green colored or bright border.

Report Cursor

A report of the location of the cursor can be defined by selecting the **[Report Cursor]** button. The button toggles the location report on and off. When on, a yellow crosshair cursor is reported on all localizer images and the RAS coordinates are displayed in red at the bottom-right corner of each viewport. You are able to modify the prescriptions even in the presence of the Report Cursor.

Zoom

You are able to zoom all the three localizer images with the Zoom slider (Figure 3-29). The range of zoom factor is from 0.5 to 8.0. The images default at a zoom factor of 1.0, i.e., no zoom.

Figure 3-29 Zoom Slider

Zoom applies for all the three localizer images with the Auto Update **[Zoom]** button (Figure 3-30) enabled. If the Auto Update **[Zoom]** button is disabled, the zoom applies only to the currently selected image.

Figure 3-30 Auto Update Area

The zoom option functions with or without prescriptions in the viewport. You are able to page through the image sets either by clicking the **[+]** and **[-]** buttons or by selecting an image and the previous Zoom value will be retained. Clicking the **[Display Normal]** button removes the zoom factor.

Display Normal

The **[Display Normal]** button brings the zoomed image to a default zoom factor of 1.0, removes the pan factor, and displays the default W/L settings. This action applies to all the three viewports if Auto Update **[Zoom]** button is enabled.

Window Width and Level

Turning on the Keep W/L feature, keeps the selected W/L for the active viewport. The W/L remains at the Keep W/L values as you click the **[+]** and **[-]** buttons to view other images within the selected viewport. If Keep W/L is not on, then as you click the **[+]** and **[-]** buttons to view other images within the selected viewport, the W/L reverts to the auto W/L values.

You are also able to change the window width and window level on Viewports 1, 2, and 3 by middle-clicking and dragging on the image. The change in window width and level applies on all the 3 localizer images if the Auto Update **[W/L]** button is enabled. During window leveling, the cursor appears as a windowing cursor.

If the Auto Update **[W/L]** button is disabled, then the window leveling applies only on the image on which the action is being done.

Pan

You are able to move (pan the image) using the right mouse button. The panning action applies on all the three viewports if the Auto Update **[Pan]** button is enabled. If the Auto Update **[Pan]** button is disabled, then the movement applies only on the image on which the action is being done. You are able to page through the image sets either by clicking the **[+]** and **[-]** buttons or by selecting an image and the previous Pan value will be retained. Clicking the **[Display Normal]** button removes the pan factor.

Reference Lines

Reference Lines are displayed on all of the viewports based on the intersections made by that localizer image with the other two localizer images by enabling the **[Loc Ref Lines]** button. The localized reference lines appear as a yellow color line, exactly at the localizers' intersection. You are not be able to make any operations, such as moving or rotating the localized reference lines.

Copy Rx

Copy Rx is used to copy the graphic prescription from a previous series to the current series, provided the current prescription has the same patient position, patient entry, landmark, mode, FOV, slice thickness, spacing, and appropriate scan plane.

Copy Rx opens a series list and displays all of the prescriptions which match the localizer image on the selected viewport. Double-clicking automatically changes the displayed image to the image used to prescribe the original series and displays the slice locations. If there are no series meeting the copy requirements, the list of series does not appear and a message posts in the Advisory panel after clicking the **[Copy Rx]** button to inform you of no matching prescriptions.

Fallback to R0

Fallback to R0 moves the slice centers from their graphically prescribed position to isocenter, along the localizer slice-select direction. This can be in either the phase or the frequency direction.

Changes to the graphic prescription are not readily noticed, but the resulting images fall back to isocenter in the slice-select direction for sagittals and coronals. The fallback occurs only in the slice-select direction of the localizer and the imaging plane determines the phase and frequency direction.

Make sure the FOV is large enough to include the anatomy of interest when the FOV falls back. Of course, as FOV increases, resolution decreases. The system does not prevent you from scanning any FOV with an offset.

If you use the fallback feature on a collapsed or projection image, the fallback occurs in the acquisition plane. For example, if you select **Fallback to R0** on a sagittal projection image from an axial 2DTOF, the FOV falls back to S/I. To adjust the L/R offset of the image, use one of the axial source images.

Reset Center

The Reset Center option allows you to graphically prescribe your locations on one slice location and redefine a new center image at another slice location.

Redefining the center image can be useful when prescribing axial orbits or shoulder images. For example, use a sagittal image where you see the optic nerves to prescribe the slice locations, then move to the center of the image and select the **[Reset Center]** button.

How Do I...

This section provides the step-by-step instructions for prescribing images. Specifically, it describes how to:

- Prescribe 2D graphic locations
  - Single and multi-group locations
  - Radial locations
- Prescribe 3D graphic locations
  - Single and multi-slab locations
  - Tracker location
- Prescribe SAT locations

Prescribe 2D Graphic Locations

Single and Multi-Group Locations

3-Plane GRx allows you to define the scan locations on a localizer image using the same landmark while viewing the exact locations on three different image planes simultaneously. Either orthogonal or oblique imaging can be used.

Use this procedure to guide you through the process of graphically prescribing the scanning range for 2D prescriptions.

1. Enter the Scanning Range parameters.
   - Choose one of the system pre-defined values or enter your own value in the text box. Use the scroll arrows to increase or decrease the selected value.

   a) Enter the FOV in centimeters.
      – Cover the area of anatomy selected for imaging. Anatomy outside the FOV in the phase direction results in aliasing.

   b) Enter the slice thickness in millimeters.

   c) Enter the slice spacing in millimeters.
      – Select a spacing that reduces cross-talk. This is typically 20% of the slice thickness. Cross-talk or overlap is caused by partial excitation of adjacent slices during RF excitation and refocusing by a 180° pulse. This causes a reduction in image contrast and SNR.
      – To reduce the effects of cross-talk choose Interleave (doubles scan time), a larger interscan spacing, or change to a 3D technique.
2. Click the **Graphic Rx** icon.
   - Displays the 3-Plane GRx screen with the system selected default images loaded in the three viewports.

Quick Steps: Prescribe 2D Single and Multi-Group Locations

1. Enter the Scanning Range parameters.
2. Click the **Graphic Rx** icon.
3. Select the image desired for the localizer.
4. Click **[Copy]** if you desire to copy a prescription from a previous series that was scanned in the same plane, mode, FOV, slice thickness and spacing.
5. Magnify the image using the Zoom slider, if necessary.
6. Press the **Shift** key and click in desired viewport to deposit the start location.
7. Click the Add handle and drag the cursor to the desired end location and release.
8. Rotate and center the slices, as needed.
9. Press the **Shift** key and click image to add another group to the prescription. Repeat steps 6 to 8 as necessary.
10. Enter new values in the corresponding text boxes to adjust the FOV, spacing, slice thickness, and phase FOV, if necessary.

Quick Steps: Prescribe 2D Single and Multi-Group Locations cont.

12. Adjust the number of slices, rotation, and start and end locations in any of the three viewports.
13. If necessary, move to desired center location and click **[Reset Center]**.
14. Click **[Accept]**.
15. Note the start, end, and center locations and number of slices.

3. Select the image desired for the localizer.
   a) If necessary, click **[Select Series]** to choose a different series to be used as a localizer.
   b) Select a series from the list.
   c) Click **[OK]**.
      – Alternatively, you may click **[-]** and **[+]** to review the previous or next image in the series and select the desired image or type the desired image number in the text box.
4. Click **[Copy]** if you desire to copy a prescription from a previous series that was scanned in the same plane, mode, FOV, slice thickness, and spacing.
   a) Select the series from the 3-Plane GRx Series List.
   b) Click **[Accept]** in the copy window.
   c) Skip to step 10.
5. Magnify the image using the Zoom slider, if necessary.
   - Enabling **Auto Update: Zoom** applies the magnification to all three viewports.
6. Press the **Shift** key and click in desired viewport to deposit the start location.
   - Click the graphic line anywhere except on either the Rotate or Add handles and drag it to the desired start location.
   - Defines the start location.
   - The start graphic line appears on the image and displays on the corresponding intersections in the other viewports.
7. Click the Add handle and drag the cursor to the desired end location and release.
   - Defines the end locations.
   - Updates the corresponding intersections in the other viewports.

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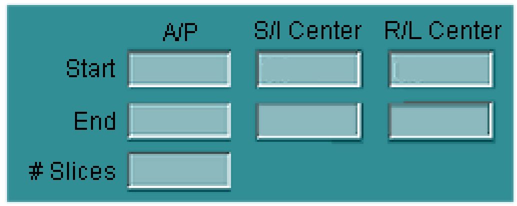
8. Rotate and center the slices, as needed.
   - Click the Rotate handles, at the center of the slice group, to turn oblique slice prescriptions.
   - Click and drag on any area of the slice line, other than the handles, to adjust the position of the entire graphic prescription.
9. Press the **Shift** key and click image to add another group to the prescription. Repeat steps 6 to 8 as necessary.
10. Enter new values in the corresponding text boxes to adjust the FOV, spacing, slice thickness, and phase FOV, if necessary.
    - This changes the FOV, spacing, and thickness for all slice groups.
11. Adjust the number of slices, rotation, and start and end locations in any of the three viewports.
    a) Click the Add handle to add or remove slices on the prescription.
    b) Click the Rotate handle at the center of the slice group for oblique prescriptions to adjust the tilt angle.
    c) Click and drag on any area of the Slice lines other than the handles to adjust the entire prescription.
12. If necessary, move to desired center location and click **[Reset Center]**.
    - Resets the center to the active viewport's location.
13. Click **[Accept]**.
    - Accepts the graphic prescription, closes the 3-Plane GRx screen, and allows you to continue with series prescription and acquisition.
    - Once you have accepted the prescription, you cannot make additional changes to the scanning range.
    - When you have prescribed multiple slices with multiple angles and you want all of the slices within each group to be acquired within a breath hold, enter the number of slices that comprises the largest group of slices as the locations before pause value. Entering a number less than this can result in more breath hold acquisitions.

14. Note the start, end, and center locations and number of slices.
    - Numeric values for the start/end locations, FOV center, and the number of slices prescribed, appear in the Scan Location text boxes in the Scanning Range area.



2D Scan Locations

Prescribe 2D Graphic Locations

Radial Locations

Radial prescriptions enable you to acquire multiple slices around a central axis in the same series. You can graphically prescribe radial locations and view their exact locations on three different image planes simultaneously. A radial or partial radial prescription can be useful for imaging, but not limited to, knees, MRCPs, myelograms, and hearts.

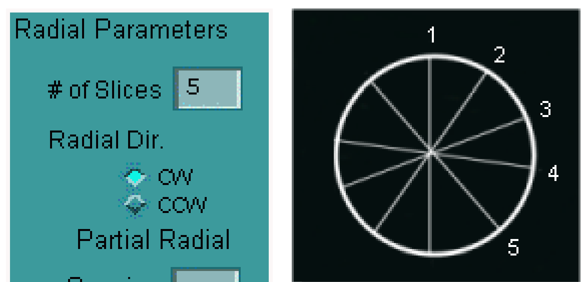
Use this procedure to guide you through the process of graphically prescribing a radial sequence.

1. Click **[New Series]**.
   - Located in the Rx Manager.
2. Enter the Imaging Parameters.
   - 2D Image Mode
   - Oblique Image Plane
   - FSE-XL, FRFSE-XL, SSFSE, SSFSE-IR, FastCard, FastCINE, or 2D FIESTA Pulse Sequence
3. Click the **Graphic Rx** icon.
   - Displays the 3-Plane GRx screen with the system selected default images loaded in the three viewports.
4. Select the image desired for the localizer.
   a) If necessary, click **[Select Series]** to choose a different series to be used as a localizer.
   b) Select a series from the list.
   c) Click **[OK]**.
   d) Alternatively, you may click **[-]** and **[+]** to review the previous or next image in the series and select the desired image or type the desired image number in the text box.
5. Select the radial direction.
   - The radial direction can be clockwise or counterclockwise.
   - The system defaults to clockwise rotation.

Quick Steps: Prescribe Radial Locations

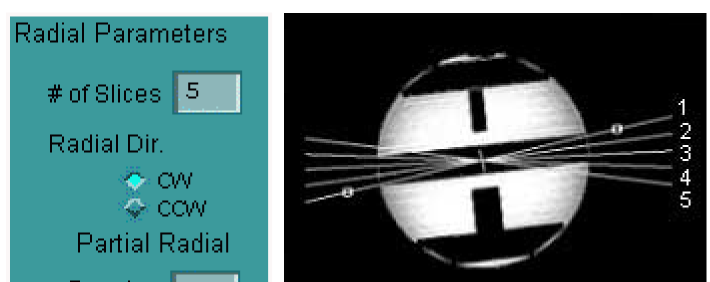
1. Click **[New Series]**.
2. Enter the Imaging Parameters.
3. Click the **Graphic Rx** icon.
4. Select the image desired for the localizer.
5. Select the radial direction.
6. Enter a value in the **# of Slices** and press the **Enter** key.
7. Enter a value in the **Partial Radial Spacing** text box and press the **Enter** key, if necessary.
8. Press the **Shift** key and click one of the images in 3-Plane GRx.
9. Adjust the radial prescription.
10. Press the **Shift** key and click image to add another group to the prescription. Repeat as necessary.
11. Click **[Accept]**.

6. Enter a value in the **# of Slices** text box and press the **Enter** key.
   - Controls the number of slices in the radial prescription.
   - The maximum number of slices in a single group is determined by the pulse sequence. If this limit is exceeded, the system does not accept the value. Enter a new value with a lower number of slices.
7. Enter a value in the **Partial Radial Spacing** text box and press the **Enter** key, if necessary.
   - For a radial graphic prescription that looks like a wagon wheel, enter a value in the **# of Slices** text box and leave the **Spacing** text box empty.



Wagon Wheel

   - For a partial radial prescription that looks like cat whiskers, enter a value in the **# of Slices** text box and the degree of the angle between the slices in the **Spacing** text box.



Cat Whiskers

8. Press the **Shift** key and click one of the images in 3-Plane GRx.
   - Radial graphics appear on the image and display the corresponding intersections in other viewports.
   - If you "draw" the slices using the cursor, you are not able to get the angles.

9. Adjust the radial prescription.
   a) Place the cursor in the center of the prescription and drag entire prescription to the desired location on image.
   b) Click the Rotate handle and turn the prescription to the desired starting slice number.
10. Press the **Shift** key and click image to add another group to the prescription. Repeat as necessary.
    - The new, active radial graphic displays blue and the first, inactive group appears yellow.
    - Changing the number of slices parameter changes the number of slices in the active (blue) group.
11. Click **[Accept]**.
    - Accepts the radial prescription, closes the 3-Plane GRx screen, and allows you to continue with series prescription and acquisition.
    - When you have prescribed multiple slices with multiple angles and you want all of the slices within each group to be acquired within a breath hold, enter the number of slices that comprises the largest group of slices as the locations before pause value. Entering a number less than this can result in more breath hold acquisitions.

NOTE: Refer to Radial Prescription in the **What Do I Need to Know About...** section of this guide for detailed information on setting the number of locations before pause during scanning.

Quick Steps: Prescribe 3D Single and Multi-Slab Locations

1. Enter the Scanning Range parameters.
2. Click the **Graphic Rx** icon.
3. Select the image desired for the localizer.
4. Click **[Copy]** if you desire to copy a prescription from a previous series that was scanned in the same plane, FOV, slice thickness, and spacing.
5. Magnify the image using the Zoom slider, if necessary.
6. Press the **Shift** key and click image in the desired viewport to deposit slab.
7. Click and drag the Add handle to display the “1” and “+” orientation for the desired slice direction order.
8. Enter new values in the corresponding text boxes to adjust the number of slabs, FOV, slice thickness, overlap locations, number of locations per slab, and phase FOV, if necessary.
9. Create multiple groups, if needed, and position the 3D volume.

Prescribe 3D Graphic Locations

Single and Multi-Slab Locations

Use 3-Plane GRx to graphically define 3D volume locations on a localizer image using the same landmark while viewing their exact locations on three different image planes simultaneously. Either orthogonal or oblique imaging can be used.

Use this procedure to guide you through the process of graphically prescribing the scanning range for 3D prescriptions.

1. Enter the Scanning Range parameters.
   - Choose one of the system pre-defined values or enter your own value in the text box. Use the scroll arrows to increase or decrease the selected value.

   a) Enter the FOV in centimeters.
      - Cover the area of anatomy selected for imaging. Anatomy outside the FOV in the phase direction results in aliasing.

   b) Enter the slice thickness in millimeters.

   c) Enter the number slices millimeters.
      - Each 3D group is able to overlap on another group for a multi group prescription. Enter the number of slices that you want to overlap between slabs within the same group to acquire a continuous series of slices—with no gaps.
      - An overlap of 25% is recommended, with uniform flip angle excitations, to minimize the venetian blind artifact on multi-slab 3D TOF acquisitions.

   d) Enter the number of scan locations per slab.
      - This defines how many slices are in each volume.

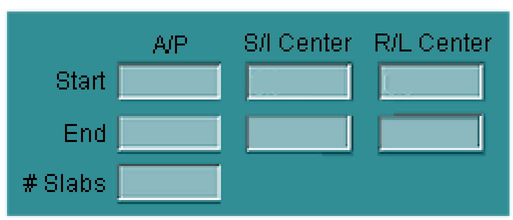
2. Click the **Graphic Rx** icon.
   - Displays the 3-Plane GRx screen with the system selected default images loaded in the three viewports.

3. Select the image desired for the localizer.
   a) If necessary, click **[Select Series]** to choose a different series to be used as a localizer.
   b) Select a series from the list.
   c) Click **[OK]**.
   d) Alternatively, you may click **[-]** or **[+]** to review the previous or next image in the series and select the desired image or type the desired image number in the text box.
4. Click **[Copy]** if you desire to copy a prescription from a previous series that was scanned in the same plane, FOV, slice thickness, and spacing.
   a) Select the series from the list.
   b) Click **[Accept]** in the Copy window.
   c) Skip to step 10.
5. Magnify the image using the Zoom slider, if necessary.
   - Enabling Auto Update: Zoom applies the magnification to all three viewports.
6. Press the **Shift** key and click image in the desired viewport to deposit slab.
   - Deposits a box representing the size of the imaging volume based on FOV, slice thickness, and number of scan locations selected.
   - Displays the corresponding intersections in the other viewports.
7. Click and drag the Add handle to display the "1" and "+" orientation for the desired slice direction order.
   - Displays the relationship of the 3D slice direction in the center of the volume. The side to which the "1" is closest is the side of the volume that begins with slice one.
   - For A, S, C, you need to drag the Add handle across to the opposite side of the volume.
8. Enter new values in the corresponding text boxes to adjust the number of slabs, FOV, slice thickness, overlap locations, number of locations per slab, and phase FOV, if necessary.

Quick Steps: Prescribe 3D Single and Multi-Slab Locations cont.

10. If necessary, move to desired center location and click **[Reset Center]**.
11. Click **[Accept]**.
12. Note the start, end, and center locations and the number of slabs.

9. Create multiple groups, if needed, and position the 3D volume.
   a) Click the Add handle to add or remove slabs on the volume prescription.
   b) Click the Rotate handle on the volume for oblique prescriptions to adjust the tilt angle.
   c) Click and drag on any area of the box other than the handles to move the entire prescription.
10. If necessary, move to desired center location and click **[Reset Center]**.
    - Redefines a new center image at another center location than where you graphically prescribed your locations.
11. Click **[Accept]**.
    - Accepts the graphic prescription, closes the 3-Plane GRx screen, and allows you to continue with series prescription and acquisition.
12. Note the start, end, and center locations and the number of slabs.
    - Numeric values for the start/end locations, FOV center, and the number of slabs prescribed, appear in the Scan Location text boxes in the Scanning Range area.



3D Scan Locations

Prescribe 3D Graphic Locations

Tracker Location

3-Plane GRx allows you to access the Tracker Rx screen to deposit a tracker prescription and view its exact locations on the image viewport within which you initially deposit it. Either orthogonal or oblique imaging can be used. The 3-Plane GRx and the tracker prescription display together in the Tracker mode and both prescriptions can be manipulated.

Use this procedure to guide you through the process of graphically prescribing a tracker for 3D Fast GRE or Fast TOF GRE/SPGR pulse sequences with SmartPrep prescriptions after prescribing your 3D volume in the 3-Plane GRx screen.

The tracker is only enabled if the SmartPrep option key is present and you have selected the SmartPrep Imaging Option.

1. Click **[Tracker]**.
    - Located on the 3-Plane GRx screen for 3D prescriptions.
    - Allows you to monitor a selected region of interest for the arrival of a contrast bolus.
2. Press the **Shift** key and click an image in any of the three viewports.
    - Deposits the tracker volume in the viewport you click.
3. Angle and move the tracker to the desired position over the main vessel.
    - Tracker placement should be no farther than ¼ above or below the center of the FOV to be scanned and should be completely contained within the vessel of interest.

    a) Turn the Rotate handles to angle the tracker prescription with your vessel of interest.

    b) Click and drag the tracker prescription to move its location.

Quick Steps: Prescribe Tracker Location

1. Click **[Tracker]**.
2. Press the **Shift** key and click an image in any of the three viewports.
3. Angle and move the tracker to the desired position over the main vessel.
4. Resize the tracker volume.
5. Reposition the 3D volume prescription, if necessary.
6. Click **[Accept]**.

4. Resize the tracker volume.
   - Recommended typical tracker size is a 20x20x20 mm volume to help minimize tracker movement.

   a) Enter a value in the **Tracker Length** text box in millimeters.
      – Tracker length is represented by the size of the line.

   b) Enter a value in the **Tracker Thickness** text box in millimeters.
      – Tracker thickness is represented by the middle cross hair.

5. Reposition the 3D volume prescription, if necessary.

6. Click **[Accept]**.
   - Accepts the Tracker prescription, closes the Tracker Rx screen, brings you back to the 3-Plane GRx screen and allows you to continue with series prescription and acquisition.

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Prescribe SAT Locations

Use the following procedure to define SAT bands on your images. 3-Plane SAT allows you to graphically prescribe SAT bands on an image from a series within the current exam while viewing your GRx in three different image planes. This option is also used for prescribing a concatenated SAT or prescribing a chemical saturation technique.

Use this procedure to guide you through the process of prescribing SAT locations during scanning.

1. Click the **SAT** icon.
   - Located in the Additional Parameters area or on the 3-Plane GRx screen.
   - Displays the SAT screen with any 3-Plane GRx locations that may have been deposited.
2. Select the image desired for the localizer.
   a) If necessary, click **[Select Series]** to choose a different series to be used as a localizer.
   b) Select a series from the list.
   c) Click **[OK]**.
   d) Alternatively, you may also click **[-]** and **[+]** to review the previous or next image in the series and select the desired image.
3. Click **[Copy]** if you desire to copy a SAT prescription from a previous series and all SATs are deselected from the current prescription.
   a) Select the series from the list.
   b) Click **[Accept]** in the Copy window.
   c) Skip to step 9.
4. Magnify the image using the Zoom slider, if necessary.
   - Enabling **Auto Update: Zoom** applies the magnification to all three viewports.

Quick Steps: Prescribe SAT Locations

1. Click the **SAT** icon.
2. Select the image desired for the localizer.
3. Click **[Copy]** if you desire to copy a SAT prescription from a previous series and all SATs are deselected from the current prescription.
4. Magnify the image using the Zoom slider, if necessary.
5. Prescribe the desired spatial saturation bands.
6. Resize and move the SAT band to its desired location.
7. Prescribe the desired concatenated spatial saturation, if necessary.
8. Prescribe the desired chemical saturation, if necessary.
9. Click **[Accept]**.

5. Prescribe the desired spatial saturation bands.
   - You are able to drop up to six SAT bands at one time on any of the three viewports if the pulse sequence supports it.
   - The intersections of the SAT bands display on the other 2 viewports.
   - The default SAT thickness is 80 mm for most sequences.
   - If you do not enter any value in the location text box, the SAT band is placed at the edge of the FOV.

   a) Click **[S]**, **[I]**, **[A]**, **[P]**, **[R]**, or **[L]** to prescribe directional spatial SAT bands.

   b) Accept the default thickness and location or enter a value for thickness and location.
      – Alternatively, position the cursor on the image at the desired location for the inside edge of the saturation band, press the **Shift** key and click.

6. Resize and move the SAT band to its desired location.

   a) Click and drag the Thickness handle to change the width of the band or type in a value in the **Thickness** text box.

   b) Click and drag the Rotate handles on the leading edge of the SAT band to turn it.

   c) Click and drag either edge of the SAT band to change its location. Do not click on the Rotate or Thickness handles to move it.

7. Prescribe the desired concatenated spatial saturation, if necessary.
   - Two concatenated saturation pulses can be placed parallel to the acquisition slice when used with a sequential series, or with an orthogonal series with two acquisitions.

   a) Click saturation bands in the slice direction.

   b) Click **[Concat SAT]**.
      – Do not change the thickness or location of the band.

8. Prescribe the desired chemical saturation, if necessary.

   a) Select **Fat**.

   b) Select **Water**.

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9. Click **[Accept]**.
   - Accepts the SAT prescription, closes the 3-Plane SAT screen, and allows you to continue with series prescription and acquisition.

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Chapter 4

Fast Spin Echo Pulse Sequences

Introduction

There are several new additions and improvements made to the Fast Spin Echo (FSE) family of pulse sequences. These new modifications improve image quality by increasing image contrast and image signal or by decreasing overall scan times.

The following pulse sequences are new or enhanced modifications of existing pulse sequences:

- Fast Spin Echo (FSE)
- T2 Fluid Attenuated Inversion Recovery (FLAIR)
- T1 Fluid Attenuated Inversion Recovery (FLAIR)
- Single Shot Fast Spin Echo-Excel (SSFSE-XL)
- Three-dimensional (3D) Fast Recovery Fast Spin Echo-Excel (FRFSE-XL)

This chapter explains the step-by-step instructions to help you learn how to:

- Activate Dynamic R1
- Prescribe a 3D FRFSE-XL Breath-Hold Sequence
- Prescribe a 3D FRFSE-XL Sequence with Respiratory Gating/Triggering

NOTE: This chapter includes new features or enhancements to FSE sequences. Refer to Volume 2 of the Signa® Infinity with Signa Select™ (ASP2) Learning and Reference Guide (direction #2292262-100) for additional FSE pulse sequences.

In addition, this chapter answers the following questions:

1. What is Dynamic R1?
2. What is Blurring Cancellation?
3. When would I use the Classic Imaging Option?
4. How do I activate a T2 Flair pulse sequence?
5. What is SSFSE-XL?
6. What is 3D FRFSE-XL?

What Do I Need to Know About...

This section presents the concepts necessary to understand FSE pulse sequences. Specifically, you need to understand:

- FSE Scan Parameters
  - Dynamic R1
  - Blurring Cancellation
  - Classic Imaging Option
- T2 FLAIR
  - Associated Imaging Options
- T1 FLAIR
  - Associated Imaging Options
- SSFSE-XL
  - Scan Parameters
  - Associated Imaging Options
  - Applications
- 3D FRFSE-XL
  - Scan Parameters
  - Associated Imaging Options
  - Applications

FSE Scan Parameters

There are several enhancements to the scanning parameters of specific FSE pulse sequences:

- Dynamic R1 with 3D FSE
- Blurring Cancellation and FSE-XL with FSEOPT or FRFSE-XL
- Classic Imaging Option with FRFSE-XL or FSEOPT

Dynamic R1

Dynamic R1 is an adaptation to the 3D FSE pulse sequence. It is designed to increase the signal-to-noise ratio (SNR) for large field of views (FOV). In a 3D FSE sequence, the analog receiver gain is typically set to adequately digitize the signal at the center of K-space, leaving the signal at the edge of K-space subject to digitalization noise. With Dynamic R1, the receiver values increase at the edge of K-space. This reduces digitalization noise and produces images with increased SNR.

The optional Dynamic R1 feature can be used with a 3D FSE pulse sequence, if the R1 value is less than 6 after Auto Prescan is completed. For optimum SNR results with Dynamic R1, make sure the Receive Gain value, R2, is 14 or higher before proceeding to scan.

Blurring Cancellation

There is a User Control Variable (CV), Blurring Cancellation, available with Fast Spin Echo-Excel (FSE-XL) or Fast Recovery Fast Spin Echo-Excel (FRFSE-XL). It uses a multiple NEX technique to average signals and thus reduce ghosting artifacts. While reducing ghost-like artifacts, it may increase scan time.

Use FSE-XL with Fast Spin Echo Optimized (FSEOPT) or FRFSE-XL with Blurring Cancellation for breath-hold abdominal imaging when a dual acquisition is required. It uses a sequential slice ordering technique that can result in a fewer mis-registration problems that typically occur with interleaved slice ordering.

Blurring Cancellation is most effective when the echo from the center K-space phase encoding represents the middle of the echo train. It has minimum effect when the center K-space echo represents the beginning or end of the echo train. Therefore, select an odd ETL value and make the effective TE the mid-point between the shortest and the longest echo. For example, if you are prescribing a 3 ETL acquisition with a minimum TE of 15 ms (the echo space), then program the effective TE to 30 ms (30 is the midpoint between echoes 15, 30, and 45).

Blurring Cancellation is never compatible with 0.5 NEX. Blurring Cancellation and NPW are only compatible with even NEX.

Blurring Cancellation is accessed by selecting the FSE-XL pulse sequence and typing in **FSE0PT** in the **PSD Name** text box or selecting **FRFSE-XL** from the Pulse Sequence window.

Use Table 4-1 for instructions on obtaining Blurring Cancellation for FSE, FRFSE, and IR pulse sequences.

Table 4-1 Blurring Cancellation PSD Selections

PSD	PSD Selection	Type in PSD
FSE	FSE-XL	FSEOPT
FRFSE	FRFSE-XL	-----
IR	FSE-IR	FRFSEOPT

Classic Imaging Option

The Classic Imaging Option with either the FRFSE-XL or FSE with FSE OPT pulse sequences can be used to potentially reduce image artifacts in the spine or pelvis. This imaging artifact is created when phase and frequency are swapped. Classic (not to be confused with Classic Fat SAT) derives its name from the original implementation of the basic Spin Echo (SE) sequence. It is the inversion of the amplitude of the slice selection gradient during the 90° excitation pulse relative to the amplitude of the slice selection gradient(s) during the 180° refocusing pulse(s). However, chemical shift (or shimming) differences can also cause incomplete refocusing of off-resonant signals and image artifacts may still be seen. Since Classic is sensitive to the center frequency, performing manual prescan insures proper center frequency.

T2 FLAIR

The T2 FLAIR selection replaces the original FLAIR selection in the Pulse Sequence window. All functions and FLAIR sequence performances can be activated through the T2 FLAIR selection. You can activate the T2 FLAIR sequence by selecting **T2 FLAIR** in the Pulse Sequence window.

NOTE: Pausing a FLAIR acquisition during scanning may cause image artifacts and should be avoided.

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 4-2, the X's indicate the imaging options available for use with the T2 FLAIR pulse sequence.

Table 4-2 T2 FLAIR Pulse Sequence Imaging Options.

Imaging Options			
	None	X	Variable Bandwidth
X	Flow Compensation		No Phase Wrap
	POMP	X	Extended Dynamic Range
	Square Pixel		Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer		Sequential
	Cardiac Gating/Triggering		Respiratory Gating/Triggering
X	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024	X	ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
		X	ASSET

NOTE: Refer to Volume 2 of the Signa® Infinity with Signa Select™ (ASP2) Learning and Reference Guide (direction #2292262-100) for additional information on this pulse sequence.

T1 FLAIR

The T1 FLAIR pulse sequence is designed to reduce the T1 weighted imaging scan time, as compared to T1 weighted Spin Echo (SE) imaging scan times. It also is designed to achieve better tissue contrast-to-noise (CNR) and tissue SNR.

You can activate the T1 FLAIR sequence by selecting **T1 FLAIR** in the Pulse Sequence window. This Pulse Sequence Database (PSD) now operates in both the Picture This and Site Protocol modes. T1 FLAIR images are annotated as “t1flair/90” in the lower left corner of images.

NOTE: The Site Protocol mode allows you to adjust prescription parameters and save the protocol in your site library.

Pausing a FLAIR acquisition during scanning may cause image artifacts and should be avoided.

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 4-3, the X’s indicate the imaging options available for use with the T1 FLAIR pulse sequence.

Table 4-3 T1 FLAIR Pulse Sequence Imaging Options.

Imaging Options			
	None	X	Variable Bandwidth
X	Flow Compensation	X	No Phase Wrap
	POMP		Extended Dynamic Range
X	Square Pixel	X	Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer	X	Sequential
	Cardiac Gating/Triggering		Respiratory Gating/Triggering
X	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
X	ZIP 1024	X	ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression

Imaging Options (Continued)			
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

NOTE: Tailored RF, Variable Bandwidth, and Sequential are inherent to this sequence and can not be turned off.

Refer to Volume 2 of the Signa® Infinity with Signa Select™ (ASP2) Learning and Reference Guide (direction #2292262-100) for additional information on this pulse sequence.

SSFSE-XL

Single Shot Fast Spin Echo-Excel (SSFSE-XL) is a purchasable option available for your MR system. It is a modification of the original SSFSE pulse sequence. This feature is designed to improve the CNR and SNR seen in MRCP images.

The SSFSE-XL sequence is activated by selecting **SSFSE** from the Pulse Sequence window. If you have this feature, the original SSFSE pulse sequence is not available to you. Differences between the two PSDs are outlined in Table 4-4.

Table 4-4 SSFSE versus SSFSE-XL

	SSFSE	SSFSE-XL
TE	Only the values from the TE pull-down list can be used.	Any value including or between the minimum and maximum values displayed on the advisory panel can be used.
TR	Not selectable; your system automatically selects the best value for you.	Any value between and including minimum to infinity can be used.

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	SSFSE	SSFSE-XL
ETL	The maximum ETL range is 184 echoes. The system automatically chooses the best ETL for you.	The maximum ETL range is 240 or 264 echoes and is dependent on your system's hardware configuration. You choose the ETL you want from the User CV window, which can only be changed if Fractional NEX Optimization is turned on. The range within which you can choose an ETL value is determined by the TE and phase matrix values.
Bandwidth	Only 20.83, 32.25, and 62.5 bandwidths can be used. The system defaults to 62.5 kHz.	The system allows 20.83, 25.00, 31.25, 41.66, and 62.5 bandwidth values to be used. System defaults to 62.5 kHz.

Scan Parameters

SSFSE-XL scan parameter modifications include the following changes:

- Flexible TE ranges
- Selectable TR values
- Additional bandwidth ranges
- Increased number of allowable echoes
- Fractional NEX Optimization

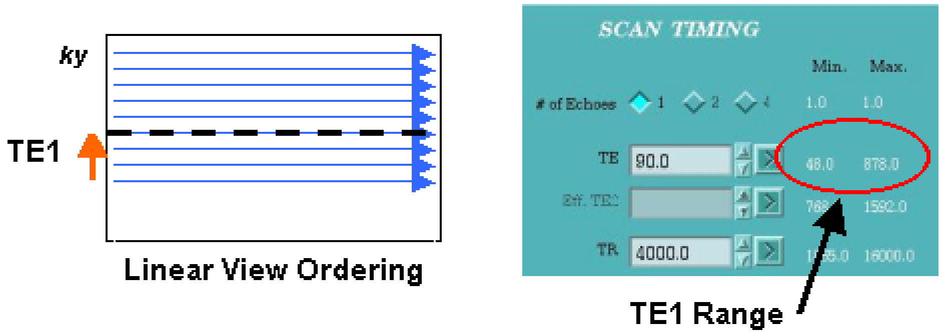
Flexible TE Range

The flexible TE range allows for two different methods of transversing K-space: Linear Phase Encoding and Reverse Phase Encoding. Both SSFSE-XL pulse sequences select the phase encoding scheme according to the prescribed TE. Linear Phase Encoding is used for short to medium range TEs. Reverse Phase Encoding is used for long range TEs. Loss of SNR from a long TE scan is minimized with Reverse Linear Phase Encoding, since it acquires more echoes earlier in the echo train compared to Linear Phase Encoding.

Refer to the following guidelines when acquiring a standard T2 SSFSE image.

- Fractional NEX Optimization should be turned off on the User CV window.
- Select a value listed for TE1. Any TE selection between the values listed in the **Min.** and **Max.** TE1 columns ensure Linear View Ordering (Figure 4-1) is applied.

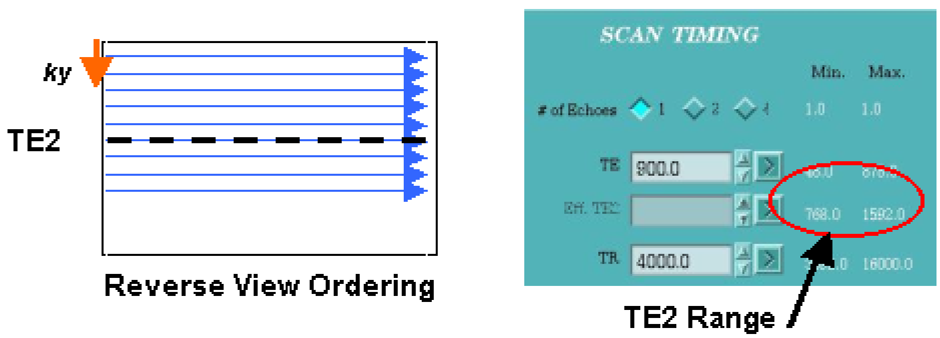
Figure 4-1 Linear View Phase Ordering Scheme



Refer to the following guideline when acquiring a MRCP or myelogram image.

- Select a value listed for TE2. Select a TE value 10 to 15 ms longer than the minimum value listed in the **Min.** and **Max.** columns for the **Eff TE** text box (TE2). This ensures Reverse View Ordering is applied.

Figure 4-2 Reverse View Phase Order Scheme



NOTE: With certain matrix combinations, you will notice a gap between the TE1 and TE2 ranges in the **Min.** and **Max.** columns. Selection of a TE value within this range may result in download failures. Other matrix combinations result in an overlap between the TE1 and TE2 values in the **Min.** and **Max.** columns. Selecting a TE value in this overlap range results in the use of the Reverse View Ordering scheme.

Selectable TR Values

TR is a programmable variable from Minimum to 16,000 ms. Selecting **Minimum** acquires the images as quickly as possible but may result in crosstalk and thus decrease image contrast, or change the contrast from slice to slice. To avoid this problem, create a pause between slices by selecting **Minimum** and entering 1 location before pause. This technique results in user control of the length of the pause and it increases tissue relaxation time between slices, thus, producing more consistent image contrast from slice to slice.

Alternatively, select a long TR value that allows the slice to be acquired and then pause during the remaining portion of the TR period before acquiring the next slice. For example, if a 4000 ms TR is entered, the slice acquisition time is less than 1 second leaving an approximate pause time of 3 seconds. Using this technique can be especially useful to increase T2 brain contrast.

The Minimum TR value is approximately the same TR value as the previous SSFSE release.

Receiver Bandwidth

Additional Receiver bandwidths (RBw) have now been incorporated into this PSD. This allows more flexibility for increasing SNR, therefore, increasing image quality.

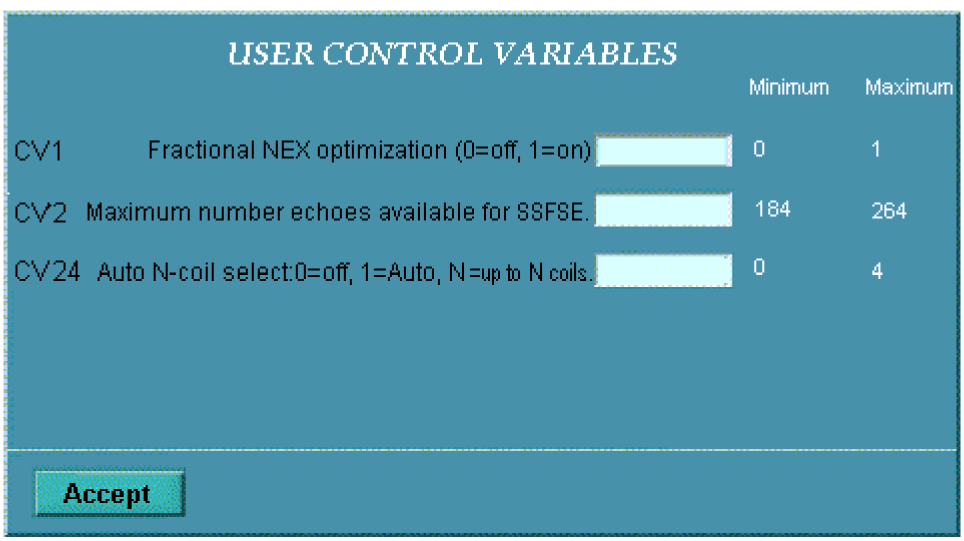
Fractional Phase FOV Ranges

A wider range of fractional phase FOV is now available. The phase FOV range is from 0.5 to 1.0. Values can be increased in increments of 0.01. This range values allows you to choose the best phase FOV to image desired anatomy, without sacrificing too much signal from your image.

User Control Variables

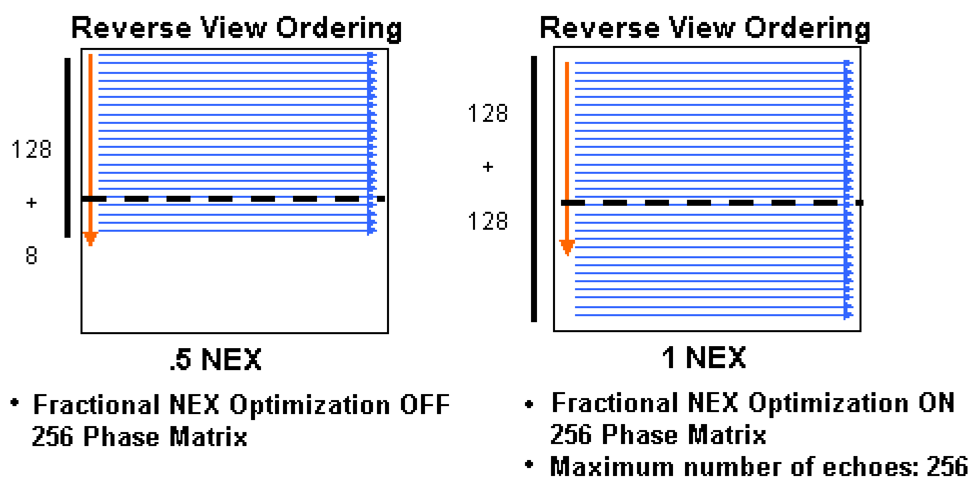
Figure 4-3 displays the User CV screen that appears with a SSFSE-XL sequence.

Figure 4-3 SSFSE-XL User CVs Screen



The “normal” behavior for SSFSE-XL is a 0.5 NEX acquisition. To override this NEX value, you must select Fractional NEX Optimization, an option selected through the User CVs screen in the Additional Parameters area. You may turn it ON to acquire additional echoes that would normally be discarded. The additional echoes increase the number of overscans and increase SNR. Fractional NEX Optimization is only available with the reverse K-space filling technique. With Fractional NEX Optimization ON, the echoes that would normally be discarded are now acquired and used to increase the number of overscans, thus increasing the SNR of the image. Image annotation reflects the fractional NEX. This option is only recommended for imaging long T2 exams, and it is particularly useful when imaging the colon and pancreas.

Figure 4-4 Fractional NEX Optimization



When Fractional NEX Optimization is OFF, a half-NEX technique is applied that uses approximately half of the phase encoding data needed to fill K-space. This technique results in the shortest scan time possible at the expense of discarded echoes to achieve the prescribed TE.

The Maximum number of Echoes option allows you to select the maximum number of echoes available for overscans. If the maximum value is entered, the system uses all available echoes resulting in the largest possible NEX. The number of echoes can be limited to acquire a NEX value between 0.5 and 1. The maximum number of echoes is either 240 or 264, and is dependent on your system’s hardware configuration.

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 4-5, the X’s indicate the imaging options available for use with the SSFSE-XL pulse sequence.

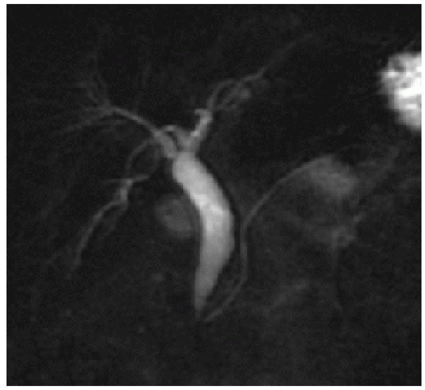
Table 4-5 SSFSE-XL Pulse Sequence Imaging Options

Imaging Options			
X	None	X	Variable Bandwidth
X	Flow Compensation		No Phase Wrap
	POMP	X	Extended Dynamic Range
	Square Pixel	X	Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer	X	Sequential
X	Cardiac Gating/Triggering	X	Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024	X	ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
		X	ASSET

Applications

SSFSE-XL sequences can be used in standard imaging to reduce motion artifacts and imaging times. With shorter scan times, breath-hold abdominal imaging can be achieved. By using long TE scans, images can also be acquired for the colon, pancreas, gallbladder, and biliary tree. Figure 4-5 displays a SSFSE-XL MRCP image acquired in a 4 second breath-hold.

Figure 4-5 SSFSE-XL MRCP



3D FRFSE-XL

3D Fast Recovery Fast Spin Echo-Excel (FRFSE-XL) pulse sequence is built on the foundation of the 3D FSE pulse sequence. It has been developed primarily to enable high-resolution images for MR cholangiopancreatography (MRCP) studies. 3D FRFSE-XL operates with the respiratory triggering, ASSET (Array coil Spatial Sensitivity Encoding Technique), fast recovery, Zerofill Interpolation (ZIP) options, sequential view-ordering, and half-NEX options, and it provides two alternative approaches to the filling of k-space. The fast recovery feature is designed to enhance the intensity of fluids that have long T2 relaxation times, while using a shortened TR time. The shortened TR time makes the high resolution images practical. Respiratory triggering is used to overcome image quality degradation due to patient breathing.

Scan Parameters

3D FRFSE is a purchasable scan feature you can activate by selecting the **3D** imaging mode in the Imaging Parameters area and selecting **FRFSE-XL** on the Pulse Sequence window. The fast recovery sequence is necessary in keeping the TR short, thereby, keeping the imaging time short. The 3D FRFSE-XL pulse sequence allows you to acquire oblique scanning planes. This provides more flexibility when performing abdominal (MRCP) scans along a specific region of interest.

Half-NEX Selection

The 3D FRFSE-XL pulse sequence supports the half-NEX option with the Single Shot view-ordering mode. The half-NEX feature reduces the imaging time to help acquire the data in the shortest possible breath-hold.

View Ordering Scheme

A sequential view ordering scheme can be used with the 3D FRFSE-XL sequence. This acquisition mode is called the Single Shot mode. It fills an entire k_y (phase) and k_x (frequency) plane of K-space in a single shot for each value of k_z (slice) and is not interleaved with k_z. The TE and ETL for this view ordering scheme are automatically calculated by your system.

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 4-5, the X's indicate the options available for use with the 3D FRFSE-XL pulse sequence.

Table 4-6 3D FRFSE-XL Pulse Sequence Imaging Options

Imaging Options			
X	None	X	Variable Bandwidth
X	Flow Compensation	X	No Phase Wrap
	POMP	X	Extended Dynamic Range
X	Square Pixel	X	Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer		Sequential
	Cardiac Gating/Triggering	X	Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
X	ZIP 1024	X	ZIP 512
X	Zip x 2	X	ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
		X	ASSET

Respiratory Gating/Triggering

The 3D FRFSE-XL pulse sequence can be used to acquire either breath-hold or respiratory gated acquisitions. Respiratory Gating/Triggering supports cross trigger to trigger conditions, where scanning extends over one respiratory cycle and the echo spacing (ESP) x ETL is greater than the trigger to trigger interval. This may be useful for times when you may need respiratory gated scans over multiple respiratory intervals at the expense of scan time. However, the **Respiratory Interval** text box does not allow type-in values with the Single Shot view ordering scheme, in other words, the only available value is 1 RR.

Zerofill Interpolation (ZIP) Options

The in-plane (ZIP 512, ZIP 1024) and through-plane (ZIP x 2, ZIP x 4) features provide sharper images and improve Maximum Intensity Projections (MIP).

Array Spatial Sensitivity Encoding Technique (ASSET)

ASSET is a technique for reducing scan time when the Torso or Torso Phased Array (PA) coil is used. Using the ASSET option with 3D FRFSE-XL decreases the imaging time to allow for shorter breath-hold acquisitions and allows for higher spatial resolution. Refer to the Imaging with ASSET chapter of this guide for ASSET details.

Variable Bandwidth Selections

Variable Bandwidth selections include values that require fractional decimation. Therefore, you are able to choose a bandwidth that optimizes ESP for your chosen parameters.

Applications

The 3D FRFSE-XL pulse sequence with the User CV of Single Shot View Ordering turned on, is used to acquire heavily T2-weighted images, such as MRCP or myelogram. The reduced imaging times allow for breath-held acquisitions or free breathing techniques with Respiratory Gating/Triggering. 3D FRFSE-XL may also be used for other T2 applications such as spine and IAC imaging.

How Do I...

This section provides the step-by-step instructions for imaging with the Dynamic R1 feature and the 3D FRFSE-XL pulse sequence. Specifically, it describes how to:

- Activate Dynamic R1
- Prescribe a 3D FRFSE-XL Breath-Hold Sequence
- Prescribe a 3D FRFSE-XL Sequence with Respiratory Gating/Triggering

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the "What You Select" column of the matrix uses two other conventions.

- N/A indicates the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

CAUTION: Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.

Activate Dynamic R1

Quick Steps: Activate Dynamic R1

1. Prescribe a large single slab 3D FSE acquisition.
2. Click **[Save Series]**.
3. Click **[Prepare to Scan]**.
4. Click **[Auto Prescan]**.
5. View the R2 value displayed above the **[Auto Prescan]** button.
6. Copy and paste the current 3D FSE highlighted series in the Rx Manager.
7. Click **[View Edit]** to view and edit the series.
8. Insert cursor in the **PSD Name** text box and type **`3dfser1`**.
9. Click **[Save Series]**.
10. Click **[Prepare to Scan]**.
11. Click **[Auto Prescan]**.
12. View the R2 value.
13. Click **[Manual Prescan]**.
14. Click and drag the Digital Gain (R2) slider in the Manual Prescan window to increase the value to 14.
15. Click **[Done]** to exit the Manual Prescan window.
16. Click **[Scan]**.

Dynamic R1 can be used with a 3D FSE pulse sequence to increase the SNR for acquiring large FOV images. If during manual prescan, the R1 of the imaging volume is less than 6, consider using Dynamic R1.

Use this procedure to activate Dynamic R1.

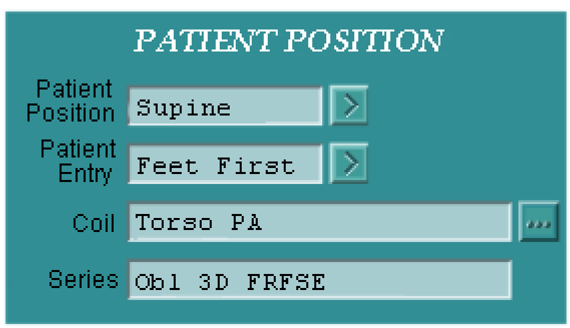
1. Prescribe a large single slab 3D FSE acquisition.
2. Click **[Save Series]**.
3. Click **[Prepare to Scan]**.
4. Click **[Auto Prescan]**.
5. View the R2 value displayed above the **[Auto Prescan]** button.
   - If the value is less than 6, then Dynamic R1 can improve the SNR.
6. Copy and paste the current 3D FSE highlighted series in the Rx Manager.
7. Click **[View Edit]** to view and edit the series.
8. Insert cursor in the **PSD Name** text box and type **`3dfser1`**.
9. Click **[Save Series]**.
10. Click **[Prepare to Scan]**.
11. Click **[Auto Prescan]**.
12. View the R2 value.
    - If it is greater or equal to 14, proceed to **[Scan]**.
    - If it is less than 14, continue with step 12.
13. Click **[Manual Prescan]**.
14. Click and drag the Digital Gain (R2) slider in the Manual Prescan window to increase the value to 14.
15. Click **[Done]** to exit the Manual Prescan window.
16. Click **[Scan]**.

Prescribe a 3D FRFSE-XL Breath-Hold Sequence

The 3D FRFSE-XL sequence is useful in clinical applications to obtain high-resolution MRCP studies, as well as obtain images in the abdomen and pelvis. This sequence can be performed as a breath-hold or can be acquired with respiratory triggering.

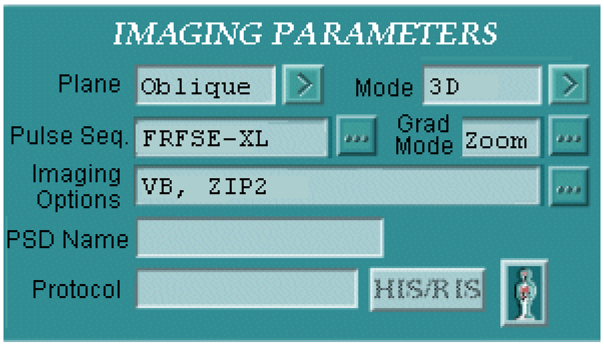
The decision matrix (Table 4-7) is only for prescribing a 3D FRFSE-XL sequence. The following example protocol is for prescribing an oblique 3D FRFSE-XL scan to be acquired in a breath-hold.

Table 4-7 3D FRFSE-XL Breath-Hold Protocol Example

3D FRFSE-XL Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Scan Rx	Acquire a localizer series	Allows Graphic Rx to become available so you can prescribe slices graphically on the localized image. Ensure the image is appropriate to prescribe the 3D volume over the anatomy of interest.
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series when the Patient Protocol window becomes active.
Patient Position		
		
Patient Position	**Supine**	Indicates the orientation of the patient. Compatible with any patient position and entry.
Patient Entry	**Feet First**	
Coil	**Phased Array > Torso PA**	Allows selection of the coil from which the signal is transmitted and received. Use a coil that produces the optimum coverage and SNR.
Series	Enter a series description in the text box.	Allows you to enter a brief description of the series being prescribed. If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

3D FRFSE-XL Protocol Example

Imaging Parameters

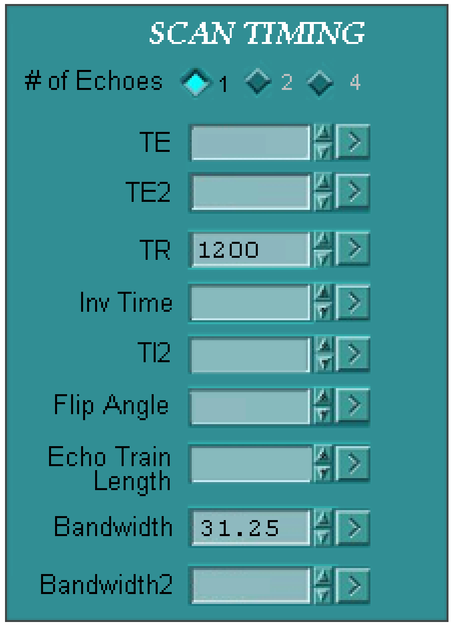


What You Select		Selection Notes
Plane	**Oblique**	Defines the scan plane of the acquisition. The oblique scan plane selection is enabled for the 3D FRFSE-XL application. For MRCP imaging, select oblique for proper angling through the anatomy.
Mode	**3D**	Prescribes a three-dimensional sequence. 3D must be selected for 3D FRFSE-XL sequences.
Pulse Seq.	**FRFSE-XL**	Prescribes the FRFSE-XL pulse sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has TwinSpeed™ gradients.
Imaging Options	**Variable Bandwidth**, **ZIPx2**	Provides appropriate options for enhancing anatomical features and reducing noise.
PSD Name	N/A	
Protocol	N/A	

3D FRFSE-XL Protocol Example

What You Select		Selection Notes

Scan Timing

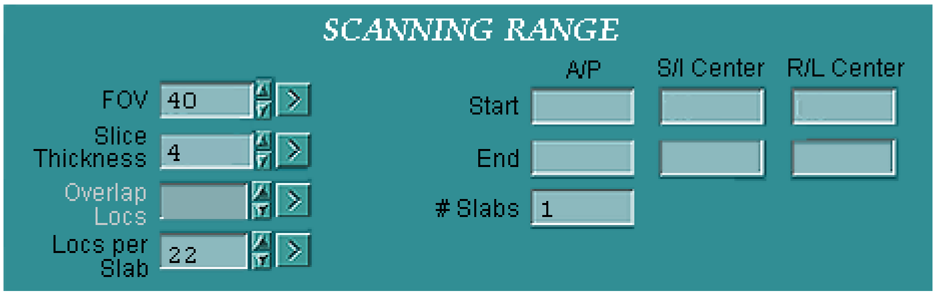


# of echoes	N/S	One echo is selected automatically if sequential view ordering is selected.
TE	N/S	The TE is automatically calculated by your system when Single Shot View Ordering (located on the User CV window) is turned on.
TE2	N/A	
TR	**1200**	
Inv Time	N/A	
TI2	N/A	
Flip Angle	N/A	
Echo Train Length	N/S	The ETL is automatically calculated by your system when Single Shot View Ordering (located on the User CV window) is turned on.
Bandwidth	**31.25**	The typical RBw value is 31.25 kHz. As the bandwidth increases, minimum TR and TE values may decrease.
Bandwidth2	N/A	

3D FRFSE-XL Protocol Example

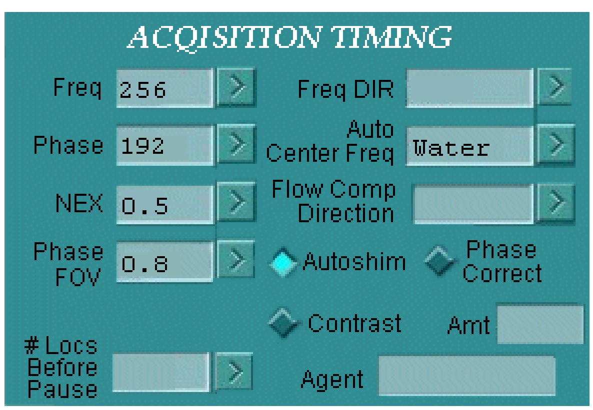
What You Select		Selection Notes

Scanning Range



FOV	Enter **40** in the text box.	Defines the size of the area imaged. The FOV is generally set as small as possible to obtain the acceptable resolution and SNR without causing aliasing from outside the FOV into the anatomy of interest. Typical values are 36 to 40 cm.
Slice Thickness	**4**	Defines the thickness of the image slice. With the ZIPx2 option on, interpolated slice thickness becomes one-half of the prescribed slice thickness. Typical values are 2 to 4 cm.
Scan Locs	**22**	Defines the number of scan locations per 3D slab. Typically, the minimum should not be less than 8.
Start, End Locations		Determines the start and end locations from the Graphic Rx program after the slab is prescribed and posts the locations here.
# Slabs	**1**	Determines the number of slabs as prescribed in Graphic Rx and posts it here. The number of slabs cannot be greater than one.

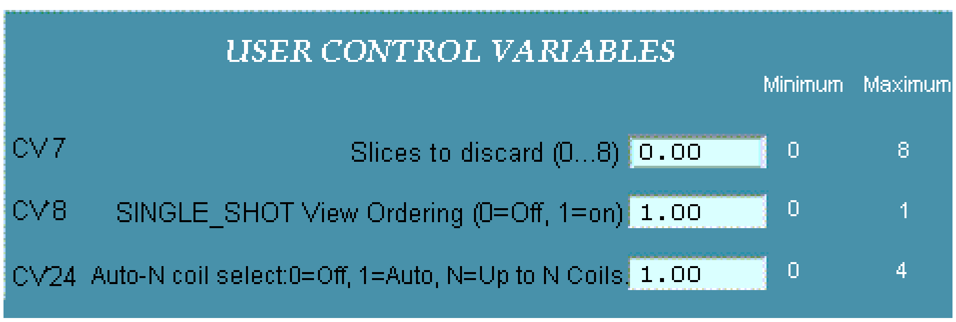
Acquisition Timing



Freq	**256**	Controls resolution. Increasing the frequency matrix decreases SNR and the number of slice locations allowed, while increasing resolution.
Phase	**192**	Controls scan time and resolution. The phase matrix cannot exceed the frequency matrix.

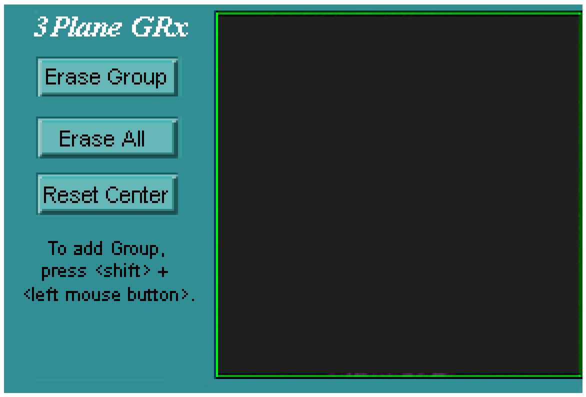
3D FRFSE-XL Protocol Example		
What You Select		**Selection Notes**
NEX	**0.5**	Half-NEX is generally used to reduce scan times and is only available if Single Shot View Ordering is turned on from the User CV window.
Phase FOV	**0.8**	Shortens scan time by scaling down the FOV in the phase direction by either 0.5, 0.6, 0.7, 0.8, or 0.9. Reduces the phase matrix and thus decreases scan time, decreases the FOV in the phase direction, and decreases SNR slightly. The phase FOV dimension is displayed next to the phase FOV factor.
Freq DIR	**Unswap**	Displays the default frequency direction, which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	Sets the peak center frequency on the water peak of the patient during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Improves image quality and is recommended for this sequence.
Phase Correct	N/A	
# of Locs Before Pause	N/A	

Additional Parameters - User CVs



Slices to discard	Enter **0.00** in the text box.	Discard zero slices since this sample protocol uses a single slab.
SINGLE_SHOT View Ordering	Enter **1.00** in the text box.	Allows you to select 0.5 NEX when the SINGLE SHOT View Ordering is one.
Accept	**[Accept]**	Confirms the selected values and closes the User CVs Additional Parameter screen.

3D FRFSE-XL Protocol Example		
What You Select		**Selection Notes**
Additional Parameters - Graphic Rx		



[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.
Image Viewport	Click the image to display the 3D volume.	Allows you to prescribe 3D slab over the anatomy of interest. Select the adjustment handles to angle the slab.
Copy Rx	**[Copy Rx]** (optional)	Copies the exact locations of the prior series if you had previously graphically prescribed a series with the same plane, FOV, and slice thickness.
Erase All	**[Erase All]** (If necessary)	Eliminates the graphic prescription from the screen and allows you to start over.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Accept	**[Accept]**	Confirms the cursor position and closes Graphic Rx.
Additional Parameters - SAT		
FAT	**On**	Turns the fat SAT technique on to suppress fat on the images.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition. Select for breath-hold acquisitions.
Scan	**[Scan]**	Initiates the acquisition.

Prescribe a 3D FRFSE-XL Sequence with Respiratory Gating/Triggering

The 3D FRFSE-XL sequence can also be performed with Respiratory Gating/Triggering to acquire images in the abdomen or pelvis.

Table 4-8 provides a brief look at an example protocol for acquiring coronal oblique 3D FRFSE-XL images with Respiratory Gating/Triggering. The parameters may vary depending on your needs.

Table 4-8 3D FRFSE-XL with Respiratory Gating/Triggering Protocol Example

Parameter	What You Select
Imaging Parameters	
Patient Position	Supine
Patient Entry	Feet First
Coil	Torso PA
Plane	Coronal Oblique
Mode	3D
Pulse Sequence	FRFSE-XL
Grad Mode	Zoom
Imaging Options	Respiratory Gating/Trigger, ZIPx2
PSD Name	N/A
Scan Timing	
# of Echoes	1
TE	N/S
TR	N/S
Flip Angle	N/A
Echo Train Length	N/S
Bandwidth	31.25
Additional Parameters - SAT	
Saturation	Fat

Parameter	What You Select
Scanning Range	
FOV	36 to 40 cm
Slice Thickness	2 to 4 mm
Locs per Slab	36
Start	Use Graphic Rx to determine start and end locations.
End	
# Slices	Cover region of interest.
Acquisition Timing	
Freq	320
Phase	256
NEX	0.5
Phase FOV	0.8
Freq DIR	S/I or unswap
Auto Center Freq	Water
Flow Comp DIR	N/A
Autoshim	On
Phase Correct	Off
Additional Parameters - User CV	
Slices to discard	0
SINGLE_SHOT View Ordering	1

NOTE: The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.

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Chapter 5

3D FIESTA Pulse Sequence

Introduction

The Fast Imaging Employing STeady-state Acquisition (FIESTA) is a fully balanced steady-state coherent imaging pulse sequence designed to produce high signal-to-noise ratio (SNR) images at very short sequence times (TRs).

This chapter explains the pulsing components and timing factors directly related to the 3D FIESTA imaging pulse sequence. It also explains the concepts and the step-by-step instructions to help you learn how to:

- Optimize 3D FIESTA Images
- Prescribe a 3D FIESTA Sequence

In addition, this chapter answers the following questions:

1. What is FIESTA?
2. When would I use a 3D FIESTA pulse sequence?
3. How do I get the shortest TR?
4. What are the imaging characteristics of a 3D FIESTA pulse sequence?
5. Which imaging options can be used with the 3D FIESTA pulse sequence?
6. What are some applications of the 3D FIESTA sequence?

What Do I Need to Know About...

This section presents the concepts necessary to understand imaging with the 3D FIESTA pulse sequence. Specifically, you need to understand the following concepts:

- 3D FIESTA Basics
- Imaging Effects
- Imaging Characteristics
- Associated Imaging Options
- Applications

3D FIESTA Basics

The Fast Imaging Employing STeady-state Acquisition (FIESTA) sequence is a fully balanced steady-state coherent imaging pulse sequence designed to produce high SNR images at very short TRs. The pulse sequence uses fully balanced gradients to re-phase the transverse magnetization at the end of each TR interval. For very short TR sequences, the resulting signal intensity is independent of TR and related to (T2/T1). More importantly, the short TRs are essential to maintain spin phase coherence. Phase coherence is required to maintain coherent transverse magnetization and eliminate artifacts generated by magnetic susceptibility induced phase shifts. Thus, the advantages of FIESTA can only be realized with very short TR where (TR << T2) and (TR << 1/b) where b is the local frequency shift caused by inhomogeneity.

NOTE: << indicates “much less than”.

Tissue contrast is generated based on the ratio of the spin-spin relaxation time (T2) and the spin-lattice relaxation time (T1). Hence, the pulse sequence accentuates the contrast of spins with high T2/T1 ratios (such as cerebral-spinal fluid, water, and fat) while suppressing signal from tissues with low T2/T1 ratios (such as muscle and myocardium).

The 3D FIESTA sequence can be used for whole body imaging and can be used in clinical applications that benefit from the differentiation of contrast between tissues of low T2/T1 ratios (low signal intensity) and high T2/T1 ratios (high signal intensity). The 3D FIESTA technique can be useful for, but not limited to, imaging structures in motion such as abdominal imaging of the bile ducts or for rapid acquisition of static structures with high spatial resolution such as the cochlea or joint imaging.

Imaging Effects

The sequence parameters have different effects that contribute to 3D FIESTA images. Table 5-1 summarizes the imaging effects relating to 3D FIESTA and is provided to help you understand the trade-offs that occur when you change the values for a particular parameter.

Table 5-1 Imaging Effects with 3D FIESTA

Parameters	Contrast (T_2/T_s)	Temporal Resolution	Spatial Resolution	SNR	Scan Time	Artifacts
TR ⇓	⇑	⇑	N/A	⇑	⇓	⇓
TE ⇓	⇑	N/A	N/A	⇑	⇓	⇓
Flip Angle ⇑	⇑	N/A	N/A	⇑	N/A	N/A
RBw ⇑	⇑	⇑	N/A	⇓	⇓	⇓
VPS ⇑	N/A	⇑	N/A	N/A	⇓	⇑
Matrix ⇑	N/A	N/A	⇑	⇓	⇑	N/A
Slice Thickness ⇓	N/A	N/A	⇑	⇓	N/A	N/A
FOV ⇓	N/A	N/A	⇑	⇓	N/A	*

NOTE: *There is not always a direct correlation between FOV and artifact. In certain instances, with anatomical size and FOV, some artifact can occur (wrap). In most other circumstances, there is not a correlation.

Imaging Characteristics

3D FIESTA sequences produce high signal to noise images with enhanced contrast and temporal resolution. This sequence provides excellent contrast between soft tissues and fluids with reduced repetition times to minimize motion artifacts.

There are several factors you should consider when using 3D FIESTA:

- 3D FIESTA supports 512 matrix.
- The TE is fixed at the minimum full value.
- When using gating turn on the Reverse Loop Order CV at the User CVs screen by typing **1**.
  - When Reverse Loop Order is OFF (0), the system scans all lines of K-space along the slab encoding direction per heartbeat; therefore, the scan time is equivalent to a number of heartbeats equal to the

number of phase encoding lines to be collected. For example, if you have a phase matrix of 128 selected with a Phase FOV of one, your scan time takes 128 heartbeats to complete.

– When Reverse Loop Order is on (1), the system collects all lines of K-space along the phase encoding direction per heartbeat; therefore, your scan time is equivalent to a number of heartbeats equal to the number of slab locations selected. For example, if you have selected a slab of 44 locations, your scan time takes 44 heartbeats to complete.

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 5-2, the X's indicate the imaging option available for use with the 3D FIESTA pulse sequence.

Table 5-2 3D FIESTA Pulse Sequence Imaging Options

Imaging Options			
X	None	X	Variable Bandwidth
	Flow Compensation	X	No Phase Wrap
	POMP	X	Extended Dynamic Range
X	Square Pixel	X	Image Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer		Sequential
X	Cardiac Gating/Triggering		Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared	X	Multi Phase
	Full Echo Train		CCOMP
X	ZIP 1024	X	ZIP 512
X	Zip x 2	X	ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

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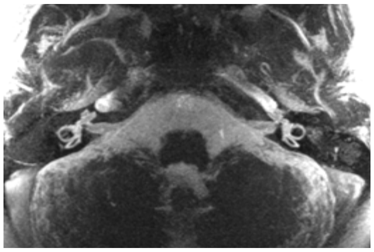
Applications

3D FIESTA imaging is intended for the whole body. Imaging applications for 3D FIESTA include screening of the spine for spinal disk hernias or disk intrusions into the spinal canal (spinal cord block), level of obstruction in hydrocephalus, biliary obstruction, cholangio-pancreatography, and in the visualization of the internal auditory canals (IACs).

Figure 5-1 3D FIESTA image of the IACs



3D FIESTA

- Recommendations for getting the shortest TR:
  - For high-resolution imaging (≤ 0.5 mm), RBw of 42 kHz appears to yield a shorter TR. This is due to gradient heating limitation. Otherwise, 125 kHz would give the shortest TR. RBw choices are 125, 100, 83.3, 62.5, 41.57, and 31.25 kHz.
  - Try smaller flip angles (40°) first and increase it slowly, every five degrees, to see if SAR limits your minimum TR. Compromise should be made between highest flip angle (70°) and shortest achievable TR (< 6 ms). The longest achievable flip angle is 90°.

WARNING: Earplugs are required for any person staying inside the scan room during 3D FIESTA scans due to its acoustic noise level.

How Do I...

This section provides the step-by-step instructions for prescribing 3D FIESTA imaging pulse sequences. Specifically, it describes how to:

- Prescribe a 3D FIESTA Sequence

This section also provides the following 3D FIESTA images and example protocols.

- Sagittal Spine
- IACs
- Body
- MRCP

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the "What You Select" column of the matrix uses two other conventions.

- N/A indicates the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

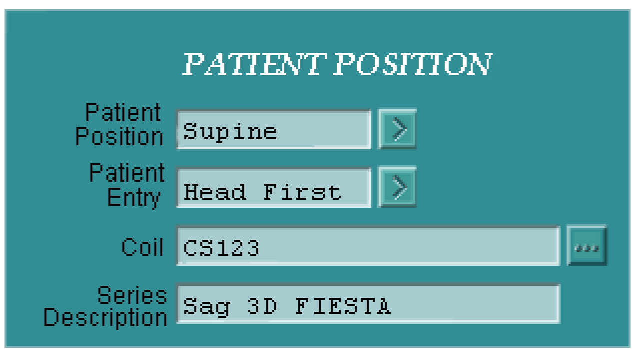
CAUTION: Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.

Prescribe a 3D FIESTA Sequence

3D sagittal images of the spine can be acquired with the FIESTA sequence. The 3D FIESTA pulse sequence accentuates cerebral spinal fluid, water, and fat, while suppressing muscle tissue.

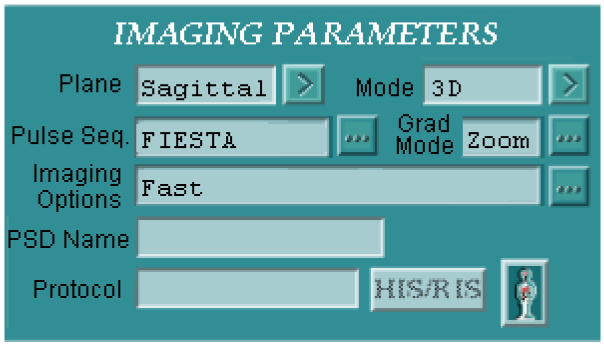
The decision matrix (Table 5-3) is only for prescribing a 3D FIESTA scan. The following example protocol in the matrix is for a 3D Sagittal Spine.

Table 5-3 3D FIESTA Protocol Example (Sagittal Spine)

3D FIESTA Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Scan Rx	Acquire a localizer series	Allows Graphic Rx to become available so you can prescribe slices graphically on the localized image.
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol window becomes active.
Patient Position		
		
Patient Position	**Supine**	Compatible with any patient position.
Patient Entry	**Head First**	Compatible with head or feet first entry.
Coil	**Phased Array > CS123**	Use a coil that produces the optimum coverage and SNR.
Series Description	Enter a series description in the text box.	If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

3D FIESTA Protocol Example		
What You Select		**Selection Notes**

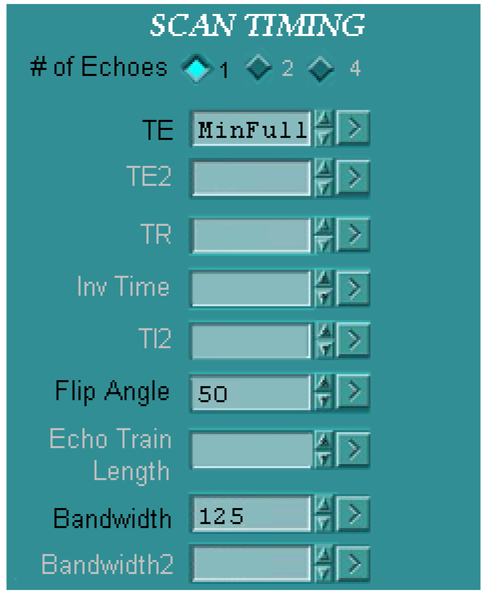
Imaging Parameters



Plane	**Sagittal**	Compatible with any scan plane, except 3-plane. Select the plane that best meets your clinical need.
Mode	**3D**	Allows prescription of a three-dimensional FIESTA sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Sequence	**FIESTA**	Allows prescription of a FIESTA pulse sequence.
Imaging Options		Select imaging options that optimize SNR, spatial resolution, number of slices and reduce motion artifacts.
PSD Name	N/A	
Protocol	N/A	

3D FIESTA Protocol Example

What You Select		Selection Notes
Scan Timing		

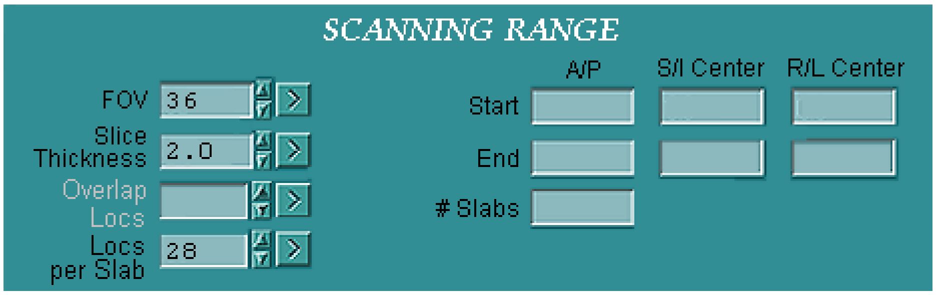


What You Select		Selection Notes
# of echoes	N/S	One echo is automatically selected.
TE	**Min Full**	The typical TE value is minimum full.
TE2	N/A	
TR	N/S	The minimum TR is selected automatically.
Inv Time	N/A	
TI2	N/A	
Flip Angle	Enter **50** in the text box.	The typical flip angle value for the spine is 45° to 55°.
Echo Train Length	N/A	
Bandwidth	**125**	The RBw choices are 125, 100, 83.3, 62.5, 41.57, and 31.2 kHz. 12 kHz yields the shortest TR for a slice thickness > 0.5 mm.
Bandwidth2	N/A	

3D FIESTA Protocol Example

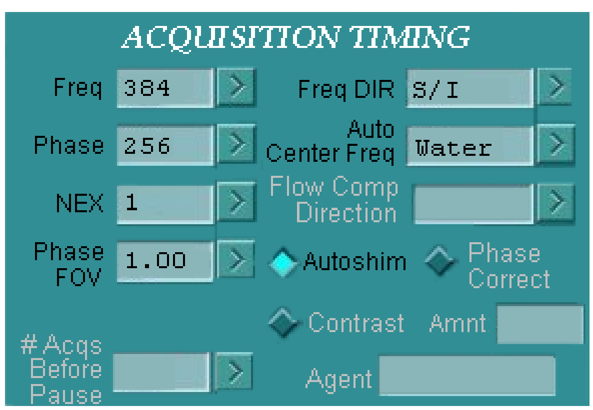
What You Select		Selection Notes

Scanning Range



FOV	Enter **36** in the text box.	Select a FOV that covers the anatomy of interest. Anatomy outside the FOV in the phase direction results in aliasing. Small FOVs produce increased resolution, decreased SNR, and can increase the minimum TE value.
Slice Thickness	**2.0**	The typical slice thickness value for a 3D spine is 2 to 3 mm. Thin slices produce increased resolution and decreased SNR.
# of Scan Locs	Enter **28** in the text box.	Available selections are 8 to 128 locations. There are always two slices on either end of the slab that are discarded. Factor these four slices into your selection.
Start, End Locations		The start and end locations are programmed from the Graphic Rx program after the slabs are prescribed.
# Slabs		Determined by the number of scan locations and the desired range of anatomy to be covered.

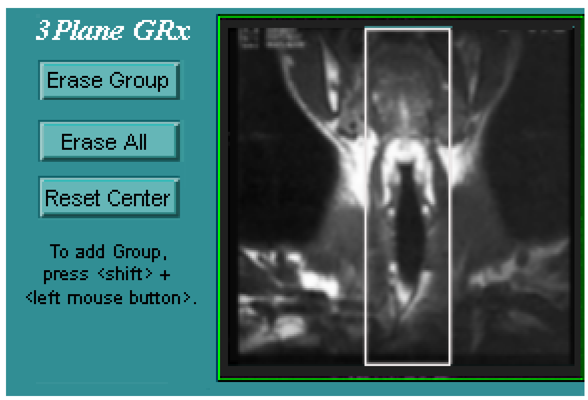
Acquisition Timing



Freq	**384**	Increasing the frequency matrix increases resolution, while decreasing SNR and the number of available slices.
Phase	**256**	Phase controls scan time and may control resolution.
NEX	**1**	One NEX for sufficient SNR and a reasonable scan time.

3D FIESTA Protocol Example		
What You Select		**Selection Notes**
Phase FOV	**1.00**	Select a phase FOV of one to prevent wrapping of anatomy.
Freq DIR	**S/I**	The direction displayed is the default frequency direction which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	The CF peak that will be set during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Turn Autoshim on when using an off center FOV and on the first series of an exam.
Phase Correct	**Off**	Provides no additional benefits and increases prescan time.
# of Acqs Before Pause	N/A	

Additional Parameters - Graphic Rx



[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.
Image Viewport	Press the **Shift** key and click the image to display the line cursor.	Prescribe the slices to display the slab for graphic prescription. Select the adjustment handles to angle, draw, and remove slabs. Position the volume to cover anatomy of interest and view the Advisory Panel to note the maximum number of slabs per acquisition and the number of acquisitions you are prescribing.
Copy Rx	**[Copy Rx]** (optional)	If you had previously graphically prescribed a series with the same plane, FOV, and slice thickness, the prescription can be copied to the exact locations of the prior series.
Erase Group	**[Erase Group]** (If necessary)	Eliminates the graphic prescription from the screen and allow you to start over.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Accept	**[Accept]**	Confirms the cursor position and close Graphic Rx.

3D FIESTA Protocol Example		
What You Select		**Selection Notes**
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Scan	**[Scan]**	Initiates the acquisition.

3D Sagittal Spine

A sagittal spine scan can be acquired with a 3D FIESTA pulse sequence. This sequence can be used for screening the spine for spinal disk hernias or intrusions into the spinal canal. The sequence accentuates cerebral spinal fluid, water, and fat, while suppressing muscle tissue. Figure 5-2 shows a sagittal image of the spine acquired with a 3D FIESTA sequence. Table 5-4 gives you a brief look at an example protocol. The parameters may vary depending on your needs.

Figure 5-2 3D FIESTA

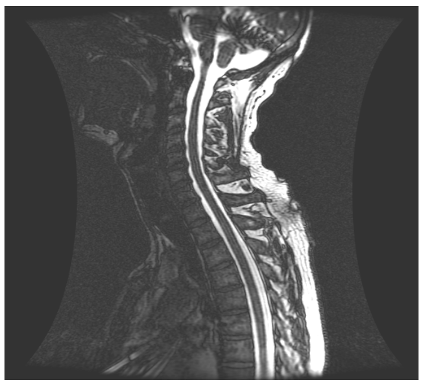


Table 5-4 3D FIESTA Example Spine Protocol

Plane	Mode	Pulse Sequence	PSD Name	TE	TR	Flip Angle	RBw	FOV	Slice Thickness	# of Scan Locs
Sagittal	3D	FIESTA	N/A	Min Full	N/A	45-55	125	~36	2 to 3	28 slices

Matrix	NEX	Phase FOV	Freq Direction	Center Frequency	Auto Shim	Phase Correct	Imaging Options	Sat Pulses	Comments
384x256	1	1	Unswap	Water	On	Off		None	CTL coil recommended

3D IACs

An axial or coronal scan of the IACs can be acquired with a 3D FIESTA pulse sequence. This sequence can be useful to produce a high signal to noise image with enhanced contrast and temporal resolution in the visualization of the cochlea. Figure 5-3 shows an axial image of the IACs acquired with a 3D FIESTA sequence. Table 5-5 gives you a brief look at an example protocol. The parameters may vary depending on your needs.

Figure 5-3 3D FIESTA

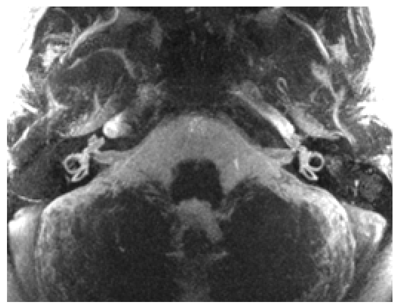


Table 5-5 3D FIESTA Example IAC Protocol

Plane	Mode	Pulse Sequence	PSD Name	TE	TR	Flip Angle	RBw	FOV	Slice Thickness	Slice Spacing
Oblique	3D	FIESTA	N/A	Min Full	N/A	70	125	16 to 28*	0.8 to 1.0	0.0

Matrix	NEX	Phase FOV	Freq Direction	Center Frequency	Auto Shim	Phase Correct	Imaging Options	Sat Pulses	Comments
512x512	1	1	Unswap	Water	On	Off		None	Dual or head coil recommended

NOTE: *Reduced FOVs attained by reducing matrix.

3D Body

An axial or coronal abdominal scan can be acquired with a 3D FIESTA pulse sequence. This sequence provides excellent contrast between soft tissues and fluids with reduced repetition times to minimize motion artifacts. Figure 5-4 shows a coronal image of the abdomen acquired with a 3D FIESTA sequence. Table 5-6 gives you a brief look at an example protocol. The parameters may vary depending on your needs.

Figure 5-4 3D FIESTA

Table 5-6 3D FIESTA Example Body Protocol

Plane	Mode	Pulse Sequence	PSD Name	TE	TR	Flip Angle	RBw	FOV	Slice Thickness	# of Scan Locs
Axial or Coronal	3D	FIESTA	N/A	Min Full	N/S	45 to 55	125	~40	3.0	20 to 40

Matrix	NEX	Phase FOV	Freq Direction	Center Frequency	Auto Shim	Imaging Options	Comments
256x192	1	1	Unswap	Water	On	ZIP x 2, 512 ZIP optional	Proper coil selection to cover anatomy

3D MRCP

An axial or coronal MR Cholangiogram (MRCP) scan can be acquired with a 3D FIESTA pulse sequence. This sequence provides enhanced contrast and temporal resolution for imaging of the bile ducts. Figure 5-5 shows an image of the bile ducts acquired with a 3D FIESTA sequence. Table 5-7 gives you a brief look at an example protocol. The parameters may vary depending on your needs.

Figure 5-5 3D FIESTA Contrast Enhanced Image

Table 5-7 3D FIESTA Example MRCP Protocol

Plane	Mode	Pulse Sequence	PSD Name	TE	TR	Flip Angle	RBw	FOV	Slice Thickness	# of Scan Locs
Axial or Coronal	3D	FIESTA	N/A	N/S	N/S	40	125	~40	2.8	44

Matrix	NEX	Phase FOV	Freq Direction	Center Frequency	Auto Shim	Phase Correct	Imaging Options	Sat Pulses	Comments
224x256	0.5	1	Unswap	Water	On	Off		None	Surface coil recommended

Chapter 6

PROSE Pulse Sequence

Introduction

This chapter presents an explanation and the details of the PROstate Spectroscopy and imaging Examination (PROSE). During a typical prostate examination, sagittal localizer images are acquired to guide the prescription of axial T1-weighted conventional Spin Echo (SE) images from the symphysis pubis to the aortic bifurcation. These images are used to assess the presence of pelvic lymph node and bone metastases and to determine if there is post-biopsy hemorrhage in the prostate. Subsequently, heavily T2-weighted high resolution Fast Spin Echo (FSE) images are acquired in the axial and coronal planes (or oblique axial and coronal planes) through the prostate and seminal vesicles to identify prostate zonal anatomy and pathology. The images, acquired with the combination of an endo-rectal coil and a pelvic or torso phased array coil, are surface coil intensity corrected with the Prostate Analytical Coil Correction (PACC) program. With the PROSE pulse sequence, the axial images are used to prescribe a three-dimensional (3D) volume containing as much of the prostate gland as possible, while excluding periprostatic lipids and the air-tissue interface of the rectum. PROSE acquires Chemical Shift Images, i.e., spectra, from the prescribed volume.

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This chapter explains the characteristics of the PROSE sequence. It also explains the major components of a prostate examination and the step-by-step instructions to help you learn how to:

- Acquire Localizer Images
- Acquire High-Resolution Images
  - Acquire Axial SE Images
  - Acquire Axial Oblique FSE Images
  - Acquire Coronal Oblique Images
- Correct Images with PACC
- Prescribe a PROSE Acquisition
- Make Prescan Adjustments
  - Examine the Spectrum
  - Manually Adjust the Homogeneity

NOTE: This chapter includes new features or enhancements of clinical spectroscopy sequences. Refer to the Signa® Infinity with Signa Select™ (ASP2) Learning and Reference Guide (direction #2292262-100) for additional clinical spectroscopy pulse sequences.

In addition, this chapter answers the following questions:

1. What is PROSE?
2. What type of localizers do I need to acquire for a PROSE examination?
3. Which imaging options can be used with a PROSE pulse sequence?
4. How do I correct for signal intensity distortions on images acquired with the endo-rectal coil?
5. What is the typical size of a PROSE ROI?
6. How can I enable VSS to use with the PROSE sequence?

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What Do I Need to Know About...

While the imaging aspects of the prostate examination are probably familiar, the spectroscopy components are probably new, and therefore the PROSE pulse sequence is discussed in more detail in this section. Specifically, you need to understand:

- PROSE Description
- Coil Placement and Selection
- Prostate Imaging
- Prostate Analytical Coil Correction
- Prostate Spectrum
- Water and Lipid Signal Suppression
- PROSE Scan Parameters
  - Imaging Options
  - Phase Encoding Matrix Selections
  - Parameters that Affect CSI Voxel Size
  - Prescribing the VOI
  - ROI Edge Sat Mask User Control Variable
- Spectroscopy Auto Prescan
- Spectroscopy Prescan
- CSI Storage

CAUTION: The safety precautions needed for a PROSE examination are identical to those required for any other Signa® examination. Review the Working Safely chapter in the Signa® Infinity with Signa Select™ (ASP2) Guide to make sure that the MR environment is as safe as possible for all patients.

PROSE Description

A complete prostate examination combines high-resolution anatomical imaging of the pelvis with three-dimensional (3D) Chemical Shift Imaging (CSI) spectroscopy of the prostate gland. An endo-rectal coil in combination with the pelvic/torso phased array coil is employed to acquire the images and spectra. A surface coil intensity program, Prostate Analytical Coil Correction (PACC), is used to correct the images.

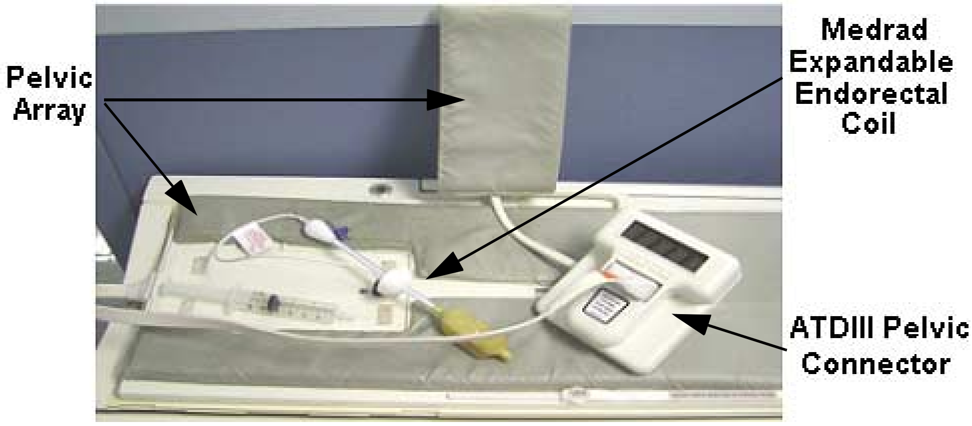
The CSI spectra are acquired with the PROSE spectroscopy pulse sequence. The PROSE pulse sequence provides, in a non-invasive manner, NMR signals (spectra) of some of the metabolites present in the prostate gland. Specifically, PROSE is version of the Point RESolved Spectroscopy (PRESS) sequence, a double spin echo sequence that uses a 90° excitation pulse with two slice selective refocusing radio frequency (RF) pulses, combined with 3D CSI phase encoding gradients to generate chemical shift images from a 3D voxel.

Coil Placement and Selection

The use of the body coil, for excitation, and an endo-rectal/pelvic phased array coil or an endo-rectal/torso phased array coil combination, for reception, allows for both the acquisition of high spatial resolution images and hydrogen spectra of the prostate, as well as coverage to the aortic bifurcation for the assessment of pelvic lymph nodes and bone metastases within the same examination. The accurate placement of the endo-rectal and pelvic/torso phased array coils is a critical aspect of the MRI/MRSI examination since it affects both the quality of the images and the spectra. Position the pelvic or torso phased array coil to cover the pelvis from the apex of the prostate to the aortic bifurcation. The endo-rectal coil is centered on the prostate in the sagittal plane and parallel to the prostate in the axial plane. Sagittal Fast Spin Echo (FSE) localizer images (reformatted in the axial plane) are used to check the positioning of the coils, which should be adjusted if necessary.

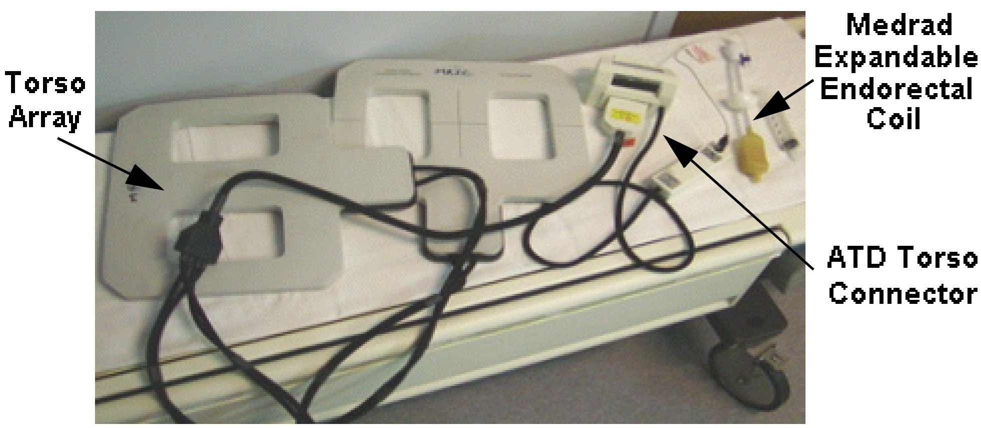
Currently, the endo-rectal coil employed is the expandable endo-rectal coil produced by Medrad (Medrad, Pittsburgh, PA). The General Electric Medical Systems (GEMS) pelvic phased array is combined with the endo-rectal coil via the ATDIII connector (Medrad, Pittsburgh, PA) as shown in Figure 6-1. The ATDIII connector is not compatible with the Low Profile Carriage Cover (LPCC).

Figure 6-1 GE Pelvic Array with the Medrad Expandable Endo-Rectal Coil



The ATD-T connector (Medrad, Pittsburgh, PA) is used when you combine the endo-rectal coil and a torso phased array coil (Figure 6-2).

Figure 6-2 GE Torso Array with the Medrad Expandable Endo-Rectal Coil



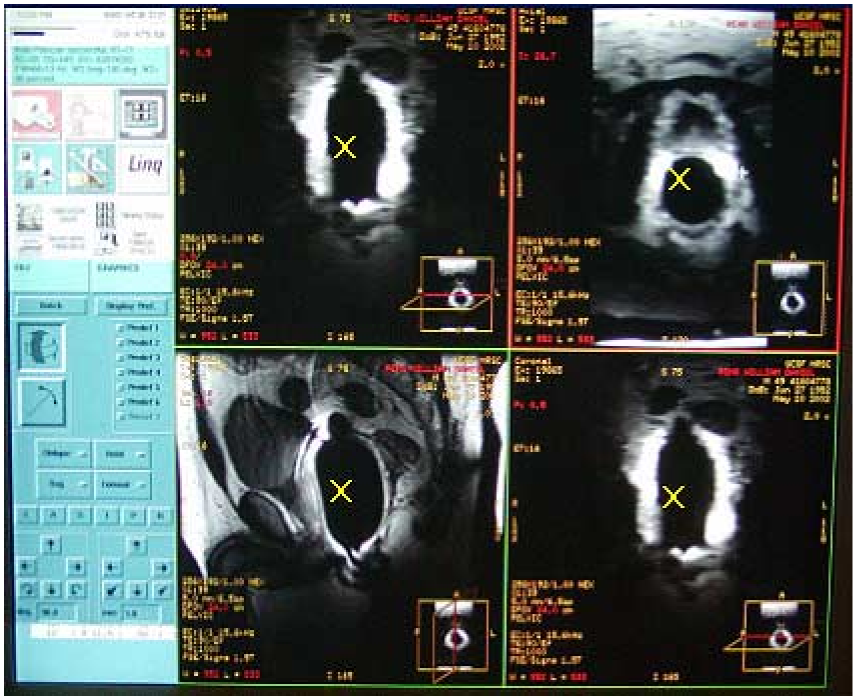
The corresponding coil selections are listed in Table 6-1.

Table 6-1 Coil Selections

Coil Configuration Name	Combiner	Coil Combination
PELVICPA	ATDIII	Pelvic Phased Array/Endo-rectal
TORSOPA	ATD	Torso Phased Array/Endo-rectal
ATDTORSO	ATD	Torso Phased Array/Endo-rectal
ADT3ENDO	ATDIII	Endo-rectal
ENDOATD	ATD	Endo-rectal

Ensure the coil chosen covers the entire prostate gland by checking the signal coverage (Figure 6-3) from superior (S) to inferior (I) using sagittal localizer FSE images. Also check the anterior (A) to posterior (P) coverage to make sure the coil is not rotated.

Figure 6-3 Checking the Coil Position



NOTE: Refer to the instructions provided with the endo-rectal coil to properly set up the coil for the prostate examination.

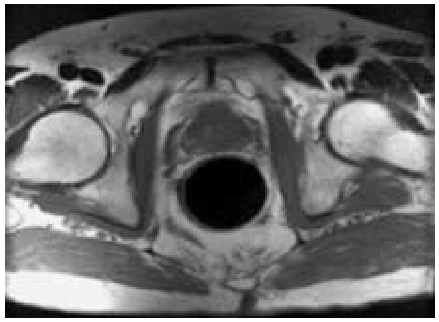
Prostate Imaging

High-resolution images are an important part of the prostate spectroscopy and imaging examination. In a typical prostate examination, a set of sagittal localizer images are used to graphically prescribe the acquisition of two sets of axial or axial oblique images, and to graphically prescribe a coronal acquisition. The localizer images are also used to check for correct coil placement.

After the acquisition of sagittal localizer images, axial T1-weighted conventional Spin Echo (SE) images are obtained from the symphysis pubis to the aortic bifurcation. These images are used to assess the presence of pelvic lymph node and bone metastases, and to determine if there is post-biopsy hemorrhage in the prostate.

Figure 6-4 is an axial oblique image of the prostate gland acquired with a T1 SE pulse sequence.

Figure 6-4 Axial Oblique SE



If it is not possible to acquire all of the T1-weighted, axial slices through the pelvic anatomy without increasing the repetition time (TR), you should acquire the images in two sets with a smaller TR (~500-766 ms).

During the acquisition of the T1-weighted images, you can reformat the sagittal images so you can check the positioning of the endo-rectal coil in the axial plane (to see the coil in the axial plane, the R/L prescription should cover the region from, roughly, R30 to L30). Adjust the endo-rectal coil, if necessary, before acquiring the T2-weighted images. Heavily T2-weighted, high-resolution, FSE images are acquired in the axial and coronal planes through the prostate and seminal vesicles to identify prostate zonal anatomy and pathology. The total time for the set up and acquisition of the MRI data is approximately 20 to 30 minutes. The specific imaging prescriptions are shown in Table 6-2.

Table 6-2 Prostate Imaging Prescriptions

	Sagittal	Axial of Pelvis	Axial or Axial Oblique[1]	Coronal or Coronal Oblique[2]	Axial or Axial Oblique
PSD	FSE	T1 SE	T2 FSE	FSE	PROSE
TE/TR	90/1000	8/766	96/6000	96/5000	130/1000
FOV	24	24	14	16	11
Thickness	5	5	3	3	25 - 40
Spacing	1.5	1.0	0.0	0.0	NA
Freq	256	256	256	256	16
Phase	192	192	192	192	8
NEX	1	1	3	3	1
Freq DIR	S/I	A/P	A/P	R/L	R/L

[1]If the spectral data are acquired obliquely to match the angle of the prostate in the S/I dimension, the axial and coronal images must also be acquired obliquely to overlay spectra and reference images.
[2]The oblique coronal images are acquired perpendicular to the oblique axial images.

Prostate Analytical Coil Correction

Typically, images acquired with receive surface coils exhibit high signal intensity in regions close to the surface coil due to the inherent reception profile of the surface coil. This high signal intensity makes it difficult to window and level, or to interpret the images. The Prostate Analytical Coil Correction program, PACC, applies a surface coil intensity correction algorithm to the high-resolution images acquired from the prostate. The reception profiles of the endo-rectal and external phased array coils are analytically determined, and the acquired images are divided by the reception profiles. The analytical, endo-rectal coil correction algorithm requires knowledge of the position of the coil relative to the uncorrected images; the PACC user interface allows you to determine the location of the coil, thereby providing the location to the correction algorithm. The following text describes the PACC user interface (Figure 6-5).

Figure 6-5 PACC Window

The PACC program runs in the Browser. Before accessing the program, select a series that you wish to correct. It is not necessary to initially select a series, but it saves time if you select the exam and series with the Browser tools prior to starting the PACC program. Refer to the steps in the **How Do I...** section of this chapter to correct images with PACC.

NOTE: Do not run the PACC tool and the Viewer or Mini Viewer at the same time. You must quit the PACC program before starting the Viewer or Mini Viewer (and vice versa).

Prostate Spectrum

Typical MR spectra from the human prostate are shown in Figure 6-6. The prominent resonance peak at ~2.6 PPM arises from the citrate molecules secreted by the prostate gland. Additional peaks that may be visible in the spectra at ~3.2, ~3.1, and ~3.0 PPM are ascribed to choline, polyamines, and creatine, respectively. Table 6-3 lists the chemical compounds that may be observed in prostate spectra.

Figure 6-6 Human Prostate NMR Spectra

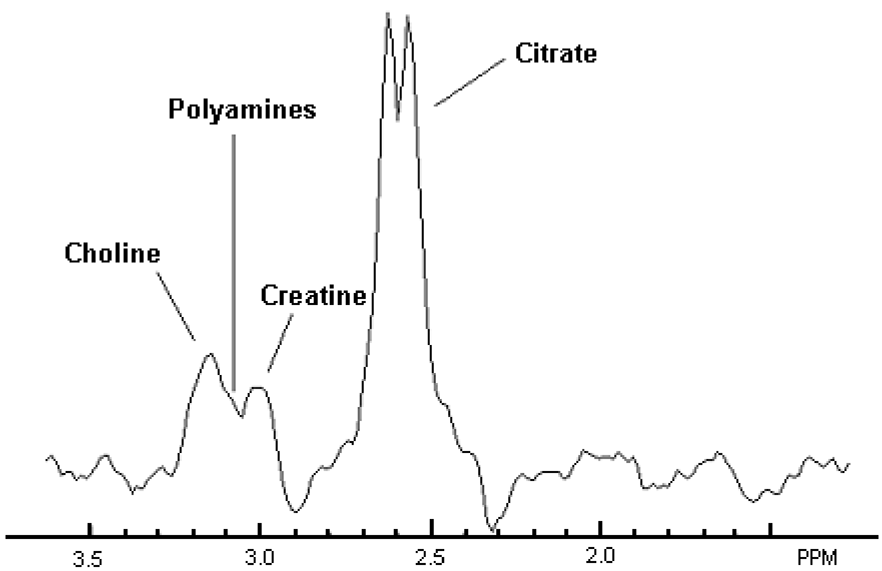


Table 6-3 Prostate Spectra Chemical Compounds

Chemical Compound	Chemical Shift (PPM)
Citrate	2.6
Choline	3.2
Polyamines	3.1
Creatine	3.0

Water and Lipid Signal Suppression

The suppression or exclusion of large water and lipid/fat signals is critical to the successful acquisition of *in vivo* spectroscopic data. In the PROBE/SVQ sequences, those used to acquire spectra from the brain, the lipid/fat signals are excluded through the careful placement and selection of a 3D PRESS or STEAM volume or voxel, and the water signals are suppressed with three CHESS (Chemical Selective Suppression), RF/gradient pulse pairs. In the prostate, however, it is often impossible to place the voxel so as to exclude tissues that contain lipid/fat. Therefore, two additional suppression methods are available in the PROSE sequence: BASING and SSRF. The SSRF (Spectral Spatial Radio Frequency) technique is the default suppression method employed in PROSE. Dual-band SSRF pulses are employed to reduce the water signal and exclude the lipid frequencies. The metabolite region is fully excited by the SSRF pulses. The SSRF excitation band is broad enough to tolerate a 25 Hz shift of the SSRF pulse and still excite the metabolites. With SSRF, the water and lipid signals are not suppressed, but instead water is partially excited while the lipids are not excited by the SSRF pulses. In addition, the SSRF pulses have a strong non-linear, phase modulation that reduces peak RF power by 40%, an important consideration for body-coil excitation. The SSRF technique is an Imaging Option that is automatically selected for PROSE. If SSRF is not selected, the BASING (BAnd Selective INversion Gradient dephasing) suppression technique is used in the PROSE sequence. This method is not recommended since it requires more peak power and is less reliable than the SSRF method. The BASING technique uses two 180° inversion RF pulses applied along the frequency axis and two crusher gradients with opposite polarity. Simply, the hydrogen atoms excited by the 180° BASING RF pulses are dephased, destroying the resulting spin echo; hydrogen atoms not excited by the RF pulses are refocused by the bipolar gradient pair.

The SSRF technique provides more consistent water, lipid, and slice selective suppression than the BASING suppression technique. Additionally, in practical use, the SSRF pulses produce fewer spectral phasing artifacts, i.e., inverted or distorted (dispersive) peaks, than produced with the BASING technique.

PROSE Scan Parameters

Acquisition parameters for the PROSE sequence are described in the following sections. These parameters allow you to acquire chemical shift images from a volume through the prostate gland as prescribed from valid localizer images of the prostate.

Imaging Options

As indicated in Table 6-4, there are three options available with the PROSE sequence: Extended Dynamic Range, Cardiac Gating/Triggering, and Spectral Spatial RF. In the default mode of the PROSE sequence, the SSRF pulses and Extended Dynamic Range (EDR) options are selected automatically. In Table 6-4, the X's indicate the options available for use with the PROSE pulse sequence.

Table 6-4 PROSE Pulse Sequence Imaging Options

Imaging Options			
	None		Variable Bandwidth
	Flow Compensation		No Phase Wrap
	POMP	**X**	Extended Dynamic Range
	Square Pixel		Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer		Sequential
X	Cardiac Gating/Triggering		Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024		ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Navigator
	Phase Sensitive	**X**	Spectral Spatial RF
	ASSET Calibration		Fluoro Trigger
			ASSET

Phase Encoding Matrix Selections

3D CSI requires three matrix selections: frequency, phase, and slice (Locs per Slab). The allowed choices for each matrix dimension are 8, 10, 12, 14, and 16. Acquisition time and the prescription of isotropic CSI voxels are the main considerations in choosing the matrix dimensions. For example, the

8x8x8, 12x12x12, and 16x16x16 choices consist of 512, 1728, and 4096 phase encoding steps, respectively. For a TR of 1000 ms, the respective acquisition times are 8:32, 28:48, and 68:16.

The 16x8x8 matrix prescription is typically used when acquiring spectra from the prostate gland — these are the frequency, phase, and slice encoding dimensions. This means that there are 8 phase encoding steps in the slice dimension with each slice containing 128 (16x8) CSI voxels. It is important to assure that the 16 phase-encode direction is the same as the larger dimension of the selected region, typically R/L.

Parameters that Affect CSI Voxel Size

The goal in selecting the field of view (FOV) and the spacing parameters is to prescribe isotropic, i.e., cubic, CSI voxels. The in-plane dimensions of a CSI voxel depend on the FOV selection and the in-plane phase encoding matrix selections. In the scan plane, square CSI pixels are obtained whenever the frequency and phase matrix selections are equal, e.g., 8x8, or when one selection is twice as large as the other, e.g., 16x8. While the first example should be clear, the second occurs from the manner in which the PROSE pulse sequence treats unequal matrix selections; the sequence adjusts the shape of the FOV to maintain square CSI pixels. For example, for a FOV of 11 cm, the 16x8x8 phase encoding matrix yields square CSI pixels with edges of 110/16 mm = 55/8 mm = 6.875 mm. An 11 cm FOV with an 8x8x8 matrix would yield pixels that are 110/8 = 13.75 mm on an edge. The pulse sequence always uses a square FOV or a rectangular FOV with a 0.5 aspect ratio, i.e., an actual 110 mm by 55 mm FOV for a 16x8 matrix with the 110 mm FOV selection.

The Spacing parameter selection should be chosen to match the square CSI pixel dimension. The PROSE sequence automatically calculates the spacing selection for the isotropic dimension once you have selected the FOV and phase encoding matrix; the first entry in the **Spacing** text box is the calculated isotropic dimension. For the example, FOV = 11 cm, matrix = 16x8x8, the first entry on the Spacing menu would be 6.9 mm (= 55/8 mm). If another Spacing value is selected the CSI voxel will not be a cubic volume.

The extent of the total phase encoded, CSI volume is determined by the FOV, the phase encoding matrix selections, and the Spacing selection. When the frequency and phase matrix selections are the same, e.g., 8x8x8, the volume is given as FOV x FOV x (Spacing x Locs per Slab). For unequal phase encoding matrix selections, e.g., 16x8x8, the volume is given as FOV x (FOV/2) x (Spacing x Loc per Slab). The phase encoding thickness in the “slice” dimension is the product of the Spacing and Loc per Slab entries (Spacing x Locs per Slab). For example, for an 11 cm FOV, a 16x8x8 matrix,

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and a Spacing selection of 7.5 mm, the slice phase encoding would cover a nominal thickness of 60 mm (= 7.5 mm x 8). The total CSI phase encoding volume for this example would be 110 mm x 55 mm x (7.5 mm x 8).

Scan Timing Parameters

The echo time (TE) of 130 ms is the default selection for PROSE data acquisitions. This echo time has been selected to optimize the appearance of the citrate resonance peak; other choices of TE may lead to substantial modulations, i.e., distortions, of the citrate peak.

A TR of 1000 ms leads to reasonable acquisition times and is a good compromise between short acquisition times and signal saturation at shorter values of TR. To avoid any signal saturation, the TR should be around five times longer than the T1 time of the resonances of interest (TR > 5 x T1), which would require a TR time greater than 3000 ms. Single voxel spectra of the brain are typically acquired with a TR of 1500 ms, while CSI brain and prostate spectra are usually acquired with a TR of 1000 ms.

In CSI acquisitions, NEX works exactly as it does in standard imaging sequences. In clinical practice, for example, a NEX value of 1 is used with the 16x8x8 phase encoding selection, and a NEX value of 2 when the 8x8x8 selection is prescribed; if the TR times are the same, the acquisition times are the same for both prescriptions. Acquisition times increase linearly with increases in NEX.

Scan Mode User Control Variable

There are four Scan Mode choices: two imaging acquisition modes (-1 and 0) and two spectroscopy acquisition modes (1 and 2). The default value is 1. Table 6-5 provides a description of each scan mode.

Table 6-5 Scan Modes

Scan Mode	Description
-1	An image of the slice centered within the voxel is acquired with thin saturation (SAT) bands placed at the edges of the prescribed voxel. This image clearly shows the location of the voxel relative to the entire slice and can be used to confirm the location of the voxel. With this selection, you should decrease the TR and TE prescribed for the spectroscopy acquisition to reduce the scan time. You may also wish to increase the FOV of the imaging acquisition to better visualize the location of the voxel relative to the anatomy around the prostate gland.

Scan Mode	Description (Continued)
0	An image of the voxel is acquired, stored, and displayed. In this acquisition, only the signal from the prescribed volume is acquired, that is, the rest of the image is blank or consists only of noise. With this selection, you should decrease the TR and TE prescribed for the spectroscopy acquisition to reduce the scan time.
1	The spectroscopy acquisition selections control the CSI reconstruction — the acquisitions are identical. The chemical shift images are reconstructed at the centers of the localizer images within the prescribed CSI volume. The CSI voxels are centered at the centers of the localizer images. When using the CSI display tool, the reference images are the exact matches to the overlaid metabolic images. This is the default mode.
2	The spectroscopy acquisition selections control the CSI reconstruction — the acquisitions are identical. The chemical shift images are reconstructed as per the acquisition prescription. The number of reconstructed chemical shift images is equal to the number of Locations per Slab and the images are centered at the phase encoding locations determined from the Spacing selection. When using the CSI display tool, the reference images are the closest match to the metabolic images. If the match is not exact, a message appears stating "Not a perfect match."

Prescribing the VOI

The PROSE ROI is graphically prescribed on the appropriate prostate localizer images, typically on the axial or axial oblique T2 FSE images. The region of interest (ROI) should be drawn so that the prostate gland is entirely within the ROI, while excluding the rectum or endo-rectal coil to minimize susceptibility artifacts.

When prescribing the volume of interest (VOI), the ROI should be placed and sized on an axial or axial oblique image. With the ROI in place, you are able to scroll through the images to determine the extent of the prostate gland. Once you have determined the third dimension of the voxel, you can either use the **[Start]** and **[End]** buttons to graphically set the thickness of the voxel, or you can deposit the ROI at the center of the VOI and enter the voxel thickness manually. Once a VOI has been set on the Graphic Rx screen, you can use the **[Reset Center]** button to reset the center of the VOI to the center of the displayed localizer slice.

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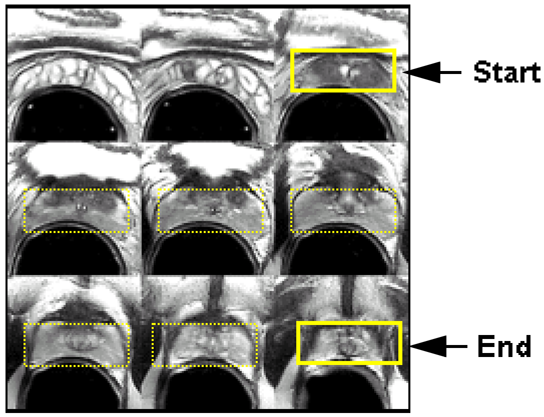
Figure 6-7 Volume Prescription

Prescription goals:

- Cover the gland, especially the peripheral zone.
- Minimize inclusion of air-interface.
- Minimize lipid inclusion.



Typical PROSE right/left (R/L), anterior/posterior (A/P), superior/inferior (S/I) dimensions are 55 mm, 35 mm, and 30 mm, respectively. These dimensions are dependent on the size of the prostate gland.

ROI Edge Sat Mask User Control Variable

There are 36 Very Selective Suppression (VSS) RF pulses available with the PROSE sequence. In the current implementation, the 36 VSS pulses are grouped in 12 sets of 3 pulses. Basically, a suppression pulse is repeated three times for each prescribed location. The following discussion describes the placement and prescription of the 12 suppression band groups.

In the default operating mode, 3 pairs of VSS RF suppression bands (6 pulses groups, a total of 18 RF pulses) are placed symmetrically around the prescribed PROSE VOI. The PROSE sequence uses the six default VSS bands to define the PROSE volume. This technique is associated with the three Overpress control variables. The prescribed PROSE volume is increased by 30% along the R/L and S/I dimensions, and 10% along the A/P dimension; the corresponding Overpress CV factors are 1.30, 1.30, and 1.10, respectively. The use of the Overpress technique to define the PROSE volume insures the entire PROSE volume is well within the passband of the RF pulses used to excite the volume. This means all of the CSI voxels within the PROSE volume are useful and reliable, i.e., a signal at the edge of an Overpress VOI is as reliable as a signal at the center of the VOI.

The pairs of VSS pulses at the edges of the VOI can be selected or deselected with the ROI edge sat mask User Control Variable, which appears on the User CVs screen. This User CV allows independent control of the three VSS pulse pairs placed at the Right/Left (R/L), Anterior/Posterior (A/P), and Superior/Inferior (S/I) edges of the VOI. Since the six default VSS bands are used to define the PROSE VOI, deselecting any of the six default VSS bands will cause the PROSE volume to increase by the “OVERPRESS” factor for that dimension which may increase lipid contamination of the spectra. Deselection of the six default VSS bands is not recommended.

The selection rules are based on assigning a numeric value to each pair; R/L = 1, A/P = 2, S/I = 4, and 0 to no VSS pulse. With these definitions, a single number from 0 to 7 can be used to select the individual pairs (1, 2, 4), the two pair combinations (the sums 3, 5, 6), the default three pair combination (7=1+2+4), or no pulses (0). Table 6-6 defines the seven possible selections.

Table 6-6 ROI Edge SAT Mask User CV

Selection	SAT Band Placement
0	Off – no VSS RF pulses.
1	S/I – the superior (S) and inferior (I) pulses only.
2	A/P – the anterior (A) and posterior (P) pulses only.
3	S/I and A/P – two pulse pairs, where 3=1+2.
4	R/L – the Right (R) and Left (L) pulses only.
5	R/L and S/I – two pulse pairs, where 5=1+4.
6	R/L and A/P – two pulse pairs, where 6=2+4.
7	R/L, A/P, and S/I – three pulse pairs, this is the default value.

You can prescribe up to six additional VSS bands (each consisting of three VSS RF pulses). Typically, four VSS RF bands are prescribed on the T2 axial localizer images using the SAT Rx, Additional Parameter screen. The two remaining bands, if used, are usually prescribed on the sagittal localizer images. The graphic prescription process provides visible feedback of the VSS band positioning and thickness. The VSS bands may be changed in thickness and angle, and may be placed anywhere on the localizer image. The thickness is given in millimeters and can be changed with the graphic prescription tools or by typing a numerical entry in the **Thickness** text box.

You can use the VSS bands to shape the rectangular PROSE voxel to better match the prostate, for example, by cutting off the corners of the ROI. VSS bands should be used to eliminate periprostatic lipid signals and the susceptibility shifted signals that may arise at the air-tissue interfaces that are included in the PRESS volume. The VSS bands are prescribed so as to suppress these lipid signals.

A typical example is shown in Figure 6-8.

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Figure 6-8 Example VSS Band Prescription

Spectroscopy Auto Prescan

In addition to the standard prescan parameters determined by the Auto Prescan (APS) processes, the PROSE sequence includes an Autoshim process to optimize the homogeneity through the PROSE voxel.

Good homogeneity is critical for a successful PROSE acquisition. The Full Width Half maximum (FWHM) line width as reported on the Advisory Panel as "LnWdth" is a good indicator of the homogeneity through the PROSE volume. The line width value should not be greater than 15 Hz for a typical 55 cmx35 cmx30 cm, PROSE voxel. Typically, the line width value increases as the PROSE volume increases.

If the reported value of the line width is greater than 15 Hz, use one of the following suggestions:

- If the line width is greater than 15 Hz, select and run APS again.
- If the line width is still greater than 15 Hz, re-prescribe the PROSE volume or the VSS bands. Be sure that you place the PROSE volume to avoid the endo-rectal coil and the air-tissue interface around the rectum. You can place the VSS bands to suppress signals from regions of high inhomogeneity. Select and run APS again.
- If the line width is still too large, you can try to reposition the PROSE volume and VSS bands again. Select and run APS again. If APS does not deliver a line width less than 16 Hz, you can try to manually adjust the homogeneity, or visually inspect the spectrum on the Spectroscopy Screen as described in the Spectroscopy Prescan section.

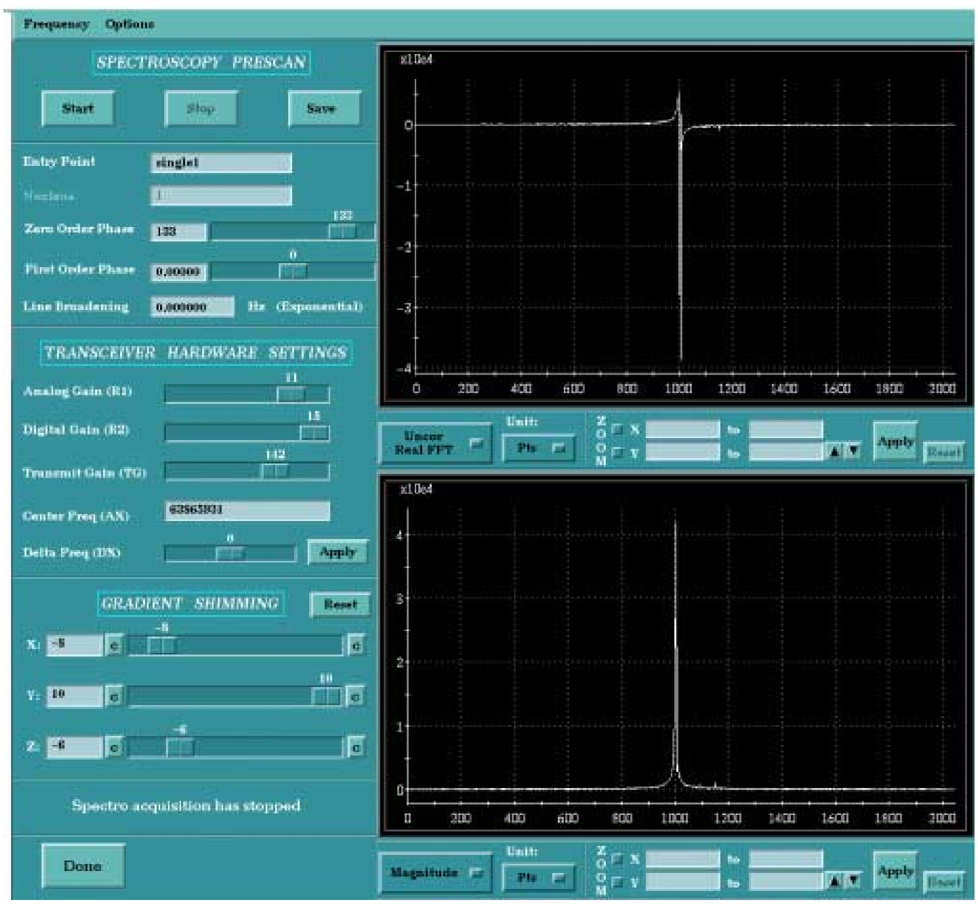
We no longer fully suppress the water signal; rather, a substantial residual water signal is required for successful CSI data reconstruction. The water suppression level (Supp Lvl) percentage, reported on the Advisory Panel, should range from 90 to 95%. Values outside of this range are acceptable, but you may wish to visually inspect the spectrum before scanning.

Spectroscopy Prescan

The Spectroscopy Prescan window, Figure 6-9, consists of two display windows, each with a display control panel just below the window, and a region at the left of the screen that allows for parameter entry, adjustment, and control. A typical PROSE spectrum from the entire PROSE volume is shown in both display windows in Figure 6-9.

You can visualize and examine the spectrum acquired from the entire PROSE volume in the Spectroscopy Prescan window. It may be possible to improve the homogeneity through the PROSE volume by manually adjusting the X, Y, and Z gradient currents in the Gradient Shimming area on the Spectroscopy Prescan window.

Figure 6-9 Spectroscopy Prescan Window



CSI Storage

After a successful PROSE data acquisition, the reconstruction process creates 256 phased corrected chemical shift images, which are drawn on one 512x512 image per prescribed slice (the number and spacing of the slices depends on the Scan Mode selection; a User CV). The chemical shift storage images are stored in a separate series in the patient database. The 256 chemical shift images from each slice cover the frequency range from 4.30 to 0.49 PPM. Spectra, metabolite and metabolite ratio images, reference images, and chemical shift images are displayed with the Functool 2 display tool on the Browser.

How Do I...

This section provides the step-by-step instructions for performing a PROSE examination. Specifically, it describes how to:

- Acquire Localizer Images
- Acquire High-Resolution Images
  - Acquire Axial SE Images
  - Acquire Axial Oblique FSE Images
  - Acquire Coronal Oblique Images
- Correct Images with PACC
- Prescribe a PROSE Acquisition
- Make Prescan Adjustments
  - Examine the Spectrum
  - Manually Adjust the Homogeneity

This section also provides a brief look at an example PROSE protocol.

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the “What You Select” column of the matrix uses two other conventions.

- N/A indicates that the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates that the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

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Acquire Localizer Images

In a typical prostate examination, FSE sagittal localizer images are acquired to guide the prescription of high-resolution axial or axial oblique images, and coronal oblique images through the prostate gland.

Table 6-7 provides a brief look at an example protocol for acquiring a sagittal localizer of the prostate. The parameters may vary depending on your needs.

Table 6-7 FSE Sagittal Localizer Protocol Example

Parameter	What You Select
Imaging Parameters	
Patient Position	Supine
Patient Entry	Feet First
Coil	Torso ATDT
Plane	Sagittal
Mode	2D
Pulse Sequence	FSE
Grad Mode	Zoom
Imaging Options	None
PSD Name	N/A
Scan Timing	
# of Echoes	1
TE	90
TR	1000
Flip Angle	N/A
Echo Train Length	16
Bandwidth	20.83

Parameter	What You Select
Scanning Range	
FOV	24 cm
Slice Thickness	5 mm
Spacing	1.5
Start	
End	
# Slices	
Acquisition Timing	
Freq	256
Phase	192
NEX	1
Phase FOV	1
Freq DIR	default
Auto Center Freq	Water
Flow Comp DIR	N/A
Autoshim	On
Phase Correct	Off

NOTE: The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.

Acquire High-Resolution Images

Acquire Axial SE Images

The axial or axial oblique SE images are used to survey the pelvis and locate the endo-rectal coil relative to the prostate gland to aid in correcting images with the PACC program.

Table 6-8 provides a brief look at an example protocol for acquiring axial or axial oblique SE images of the prostate. The parameters may vary depending on your needs.

Table 6-8 SE Axial Protocol Example

Parameter	What You Select
Imaging Parameters	
Patient Position	Supine
Patient Entry	Feet First
Coil	Torso ATDT
Plane	Axial or Axial Oblique
Mode	2D
Pulse Sequence	SE
Grad Mode	Zoom
Imaging Options	None
PSD Name	N/A
Scan Timing	
# of Echoes	1
TE	8
TR	766
Flip Angle	N/A
Echo Train Length	N/A
Bandwidth	20.83

Parameter	What You Select
Scanning Range	
FOV	24 cm
Slice Thickness	5 mm
Spacing	1.0
Start	Use Graphic Rx to determine start and end locations.
End	
# Slices	Cover the entire pelvis.
Acquisition Timing	
Freq	256
Phase	192
NEX	1
Phase FOV	1
Freq DIR	A/P
Auto Center Freq	Water
Flow Comp DIR	N/A
Autoshim	On
Phase Correct	Off

NOTE: The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.

If it is not possible to acquire all of the T1-weighted, axial slices through the pelvic anatomy without increasing the repetition time (TR), you should acquire the images in two sets with a smaller TR (~500 to 766 ms).

Acquire High-resolution Images

Acquire Axial Oblique FSE Images

High-resolution images are an important part of the prostate spectroscopy and imaging examination. The axial or axial oblique FSE images can be used to prescribe the PROSE volume for the PROSE sequence.

Table 6-9 provides a brief look at an example protocol for acquiring axial or axial oblique FSE images of the prostate. The parameters may vary depending on your needs.

Table 6-9 FSE Axial Oblique Protocol Example

Parameter	What You Select
Imaging Parameters	
Patient Position	Supine
Patient Entry	Feet First
Coil	Torso ATDT
Plane	Axial or Axial Oblique
Mode	2D
Pulse Sequence	FSE
Grad Mode	Zoom
Imaging Options	None
PSD Name	N/A
Scan Timing	
# of Echoes	1
TE	96
TR	6000
Flip Angle	N/A
Echo Train Length	16
Bandwidth	20.83

Parameter	What You Select
Scanning Range	
FOV	14 cm
Slice Thickness	3 mm
Spacing	0.0
Start	Use Graphic Rx to determine start and end locations.
End	
# Slices	Cover entire prostate.
Acquisition Timing	
Freq	256
Phase	192
NEX	3
Phase FOV	1
Freq DIR	A/P
Auto Center Freq	Water
Flow Comp DIR	N/A
Autoshim	On
Phase Correct	Off

NOTE: The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.

Acquire High-resolution Images

Acquire Coronal Oblique Images

High-resolution images are an important part of the prostate spectroscopy and imaging examination. In addition to the axial SE and FSE images, coronal FSE images are also a necessary component of a PROSE examination. The coronal images may allow for reformatting of the CSI data in another plane.

Table 6-10 provides a brief look at an example protocol for acquiring coronal FSE images of the prostate. The parameters may vary depending on your needs.

Table 6-10 FSE Coronal Protocol Example

Parameter	What You Select
Imaging Parameters	
Patient Position	Supine
Patient Entry	Feet First
Coil	Torso ATDT
Plane	Coronal or Oblique Coronal
Mode	2D
Pulse Sequence	FSE
Grad Mode	Zoom
Imaging Options	None
PSD Name	N/A
Scan Timing	
# of Echoes	1
TE	96
TR	5000
Flip Angle	N/A
Echo Train Length	16
Bandwidth	20.83

Parameter	What You Select
Scanning Range	
FOV	16 cm
Slice Thickness	3 mm
Spacing	0.0
Start	Use Graphic Rx to determine start and end locations.
End	
# Slices	Cover entire prostate.
Acquisition Timing	
Freq	256
Phase	192
NEX	3
Phase FOV	1
Freq DIR	default
Auto Center Freq	Water
Flow Comp DIR	N/A
Autoshim	On
Phase Correct	Off

NOTE: The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.

Correct Images with PACC

Prostate images acquired with an endo-rectal coil usually exhibit bright signals near the coil. To correct for this brightness, use the PACC program to apply a surface coil intensity correction algorithm to the high-resolution images. This program allows you to determine the location of the endo-rectal coil relative to the uncorrected images, thereby providing the location to the correction algorithm. The corrected images are used to prescribe a 3D volume containing the prostate gland.

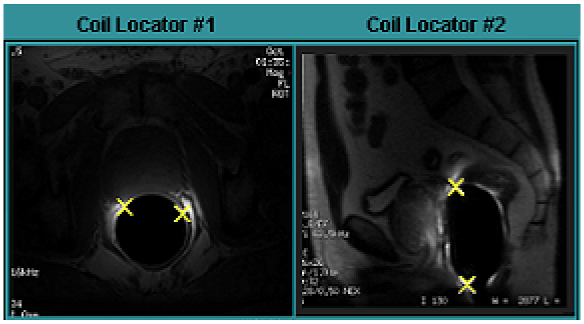
Use this procedure to correct images acquired with an endo-rectal coil.

1. Select the series of the examination you wish to correct with PACC from the Browser.
   - It is not necessary to initially select a series, but it saves time if you select the Exam and Series with the Browser tools prior to starting the PACC program.
2. Click **[PACC]** on the right-most Browser panel to access the PACC program.
   - The PACC graphic user interface, with four display windows and a simple control panel, displays on the desktop.
   - If you have selected a series on the Browser, three images display in the PACC window.
3. As necessary, click **[Exam]**, **[Series]**, and **[Image]** to select a sagittal image that you will use to locate the endo-rectal coil in the sagittal plane.
4. Display the SE axial/oblique coil locator image in the upper right display window.
   a) Click anywhere in the upper right display window.
   b) As necessary, click **[Exam]**, **[Series]**, and **[Image]** to select an axial/oblique image that you will use to locate the endo-rectal coil in the axial plane.
      – One of the coil locator images must be in the axial/oblique plane and the other in the sagittal.

Quick Steps: Correct Images with PACC

1. Select the series of the examination you wish to correct with PACC from the Browser.
2. Click **[PACC]** on the right-most Browser panel to access the PACC program.
3. As necessary, click **[Exam]**, **[Series]**, and **[Image]** to select a sagittal image that you will use to locate the endo-rectal coil in the sagittal plane.
4. Display the SE axial/oblique coil locator image in the upper right display window.
5. Display the FSE axial/oblique series to be corrected in the lower left display window..
6. Choose two coil location pick points on each of the images in the upper left and upper right display windows.
7. When you are satisfied with your selections, click **[Correct Series]**.
8. Click **[Quit]** to exit the PACC user interface at any time when image correction is complete.

5. Display the FSE axial/oblique series to be corrected in the lower left display window.
    a) Click anywhere in the lower left display window.
    b) As necessary, click **[Exam]**, **[Series]**, and **[Image]** to display any image in the series to be corrected.
6. Choose two coil location pick points on each of the images in the upper left and upper right display windows.
    - Set the **[Set/Show]** toggle to **[Set]** to select the points near the coil.
        – Refer to the example of the RAS coordinates of the selected points displayed below.



PACC Window

7. When you are satisfied with your selections, click **[Correct Series]**.
    - The correction may take some time, so be patient. While a correction is in progress, the PACC user interface will not respond to any actions except **[Cancel]**.
    - If the correction completes successfully, the message "Correction Successful" appears in the status bar. Otherwise an error message accompanied by a pop-up error message window is displayed.
    - The corrected axial/oblique images are displayed in the lower right display window.
8. Click **[Quit]** to exit the PACC user interface at any time.

NOTE: Do not run the PACC tool, and the Viewer or Mini Viewer at the same time. You must quit the PACC program before starting the Viewer or Mini Viewer (and vice versa).

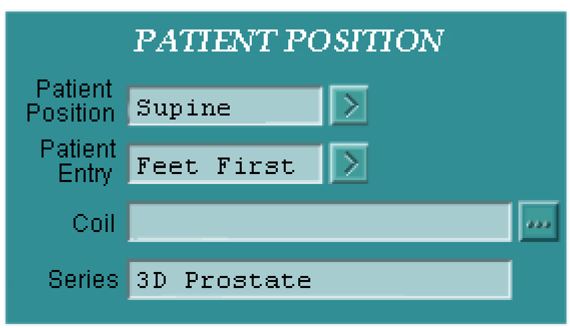
Prescribe a PROSE Acquisition

PROSE is 3D multi-voxel spectroscopy sequence used to produce spectra from the human prostate gland area. The PROSE sequence is one segment of a comprehensive prostate examination. The following entries for the PROSE pulse sequence decision matrix allows you to acquire chemical shift images from a volume through the prostate gland as selected from valid localizer images of the prostate.

This decision matrix (Table 6-11) describes a PROSE sequence prescription that acquires spectra from isotropic CSI voxels that are 6.9 mm on each edge. Any changes in the suggested FOV (11 cm), phase encoding matrix selection (16x8x8), frequency direction (R/L), or spacing (6.9) may result in non-isotropic voxels, decreased SNR, or dramatic changes in scan time.

Table 6-11 PROSE Sequence Protocol Example

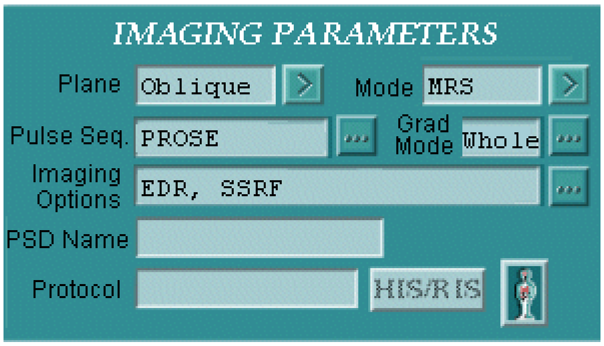
PROSE Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Rx Manager area	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol screen becomes active.
Patient Position		



Patient Position	**Supine**	3D PROSE is used in prostate scanning, so the patient position and entry selections reflect that.
Patient Entry	**Feet First**	
Coil	**ENDOATD** or **ATD3ENDO**	Select the name given for the compatible coil (refer to Table 6-1 for all compatible coils). Select the coil name that only turns on the endo-rectal portion of the coil. Turning on the body portion of the coil results in too many images.
Series	Type in a series description in the text box.	If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and imaging options.

PROSE Protocol Example		
What You Select		**Selection Notes**

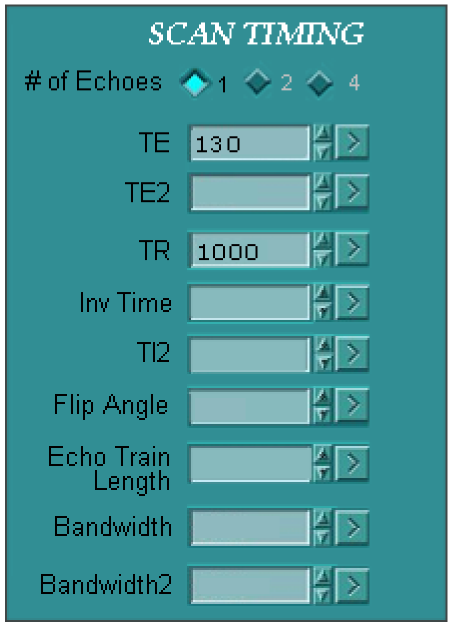
Imaging Parameters



Plane	**Oblique**	An axial oblique prescription that matches the tilt of the prostate gland, helps in the placement of the PROSE volume, such that it avoids the rectum and the endo-rectal coil. PROSE is compatible with any scan plane, including oblique and 3-Plane Localizers. Select the same plane as the plane of the localizer images — this differs from the normal image prescription process.
Mode	**MRS**	PROSE is a small volume selective sequence, which is enabled with the MRS selection.
Grad Mode	**Whole**	Activate the Whole gradient mode of operation for the best shim. This text box is only available if your system has Twin gradients.
Pulse Seq	**PROSE**	Select PROSE.
Imaging Options	**EDR, SSRF**	EDR (Extended Dynamic Range) and SSRF (Spectral Spatial RF) are default selections.
PSD Name	**N/A**	
Protocol	**N/A**	

PROSE Protocol Example

What You Select		Selection Notes
Scan Timing		
# of echoes	**1**	Only 1 echo is allowed.
TE	**130**	A TE value of 130 ms is recommended for best visualization of the citrate resonance peaks.
TE2	N/A	
TR	**1000**	If the scan mode = 1, select a typical TR of 1000 ms. A longer TR results in increased SNR at the expense of increased scan time. If the scan mode = 0, (voxel image) select the shortest allowed TR.
TI	N/A	
Flip Angle	N/A	
Echo Train Length	N/A	
Bandwidth	N/S	The Receiver Bandwidth is automatically selected for spectroscopy scans and cannot be programmed.
Bandwidth 2	N/A	



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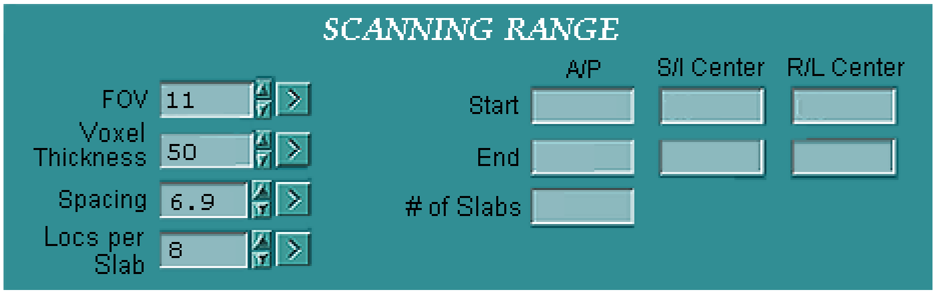
PROSE Protocol Example

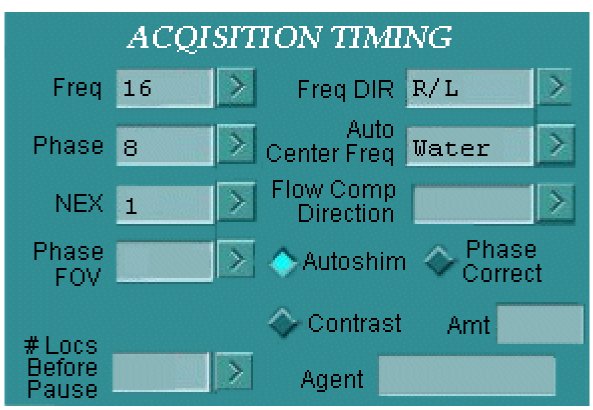
What You Select		Selection Notes

Scanning Range



FOV	**11**	An 11 cm FOV when used with 16 phase encoding steps along the frequency direction, yields a 6.9 mm CSI voxel edge.
Voxel Thickness	**50**	Choose a voxel thickness large enough to cover the anatomy or pathology. The lower limit is 3 mm and the upper limit is 100 mm. The voxel thickness varies with the size of the prostate gland. A typical start value is 50 mm. The actual value is determined by defining the Start and End locations in Graphic Rx.
Spacing	**6.9** (should be the first default selection)	The first menu option is calculated for an isotropic voxel. The system automatically calculates this based on your chosen FOV and matrix size. This value is not available until after matrix values and Graphic Rx locations are determined.
Locs per Slab	**8**	Eight is the recommended value. Acceptable values are even numbers from 8 to 16. As this value increases, scan time dramatically increases.

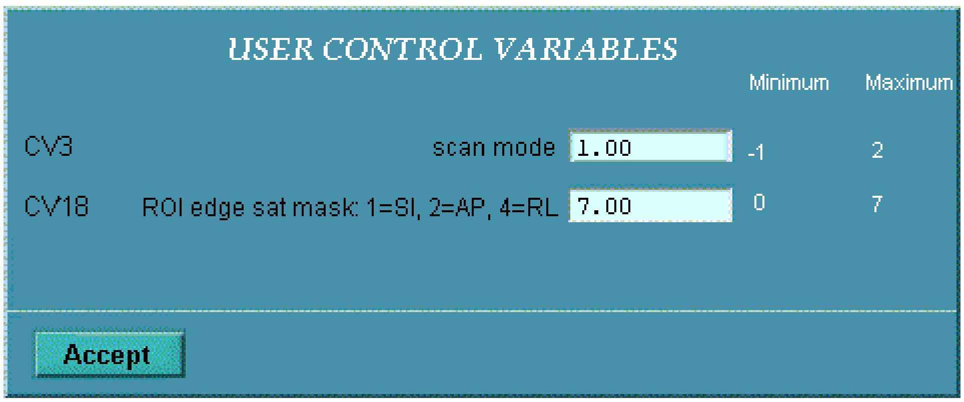
Acquisition Timing



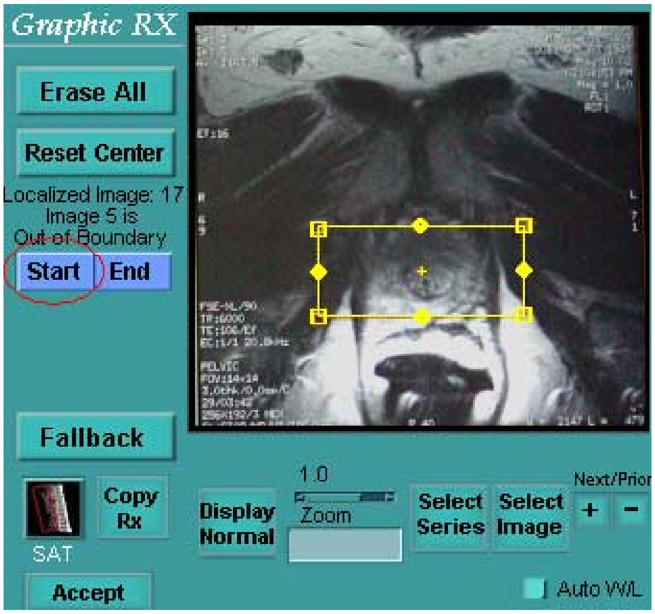
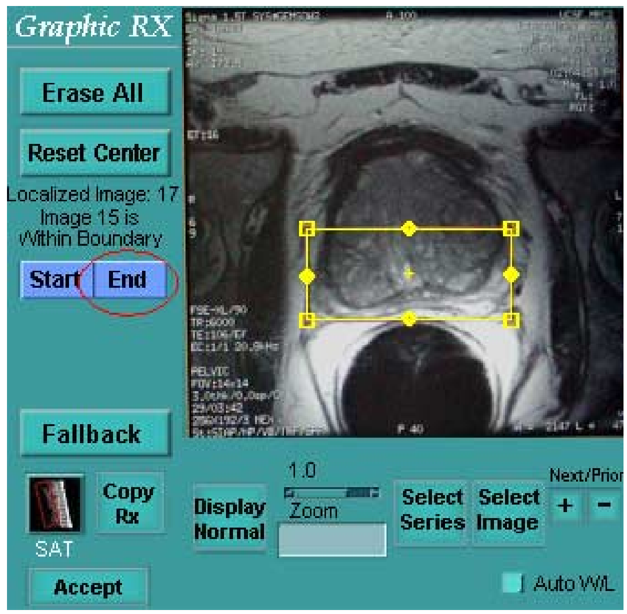
Freq	**16**	The 16 and 8 selections yield isotropic CSI voxels that are 6.9 mm on an edge.
Phase	**8**	
NEX	**1**	As the NEX value increases, the SNR increases and the scan time increases.

PROSE Protocol Example		
What You Select		**Selection Notes**
Freq DIR	**Unswap**	Select the default value. The frequency direction should correspond to the long anatomical dimension, typically the R/L dimension for a body scan.
Auto Center Freq	**Water**	Select water.
Flow Comp DIR	N/A	
Autoshim	**On**	Select Autoshim to make the volume of interest as homogeneous as possible.
Phase Correct	N/A	

Additional Parameters - User CVs



Scan Mode	**1.00**	One (1) allows CSI images to reconstruct at the center of the localizer images within the PROSE volume.
ROI edge sat mask	**7.00**	Enables the placement of VSS bands around the VOI. Enter 7, this enables R/L, A/P and S/I SAT band placement.
Accept	**[Accept]**	Confirms the User CV selections and closes the window.

PROSE Protocol Example		
What You Select		**Selection Notes**
Additional Parameters - Graphic and SAT Rx		
		
Select Series	**[Select Series]**	Select the surface coil intensity corrected axial or axial oblique T2 FSE images.
Image Viewport	Click the image to display the ROI.	Position the ROI to cover the entire prostate gland, while excluding the rectum and endo-rectum coil to minimize susceptibility artifacts. Click and drag the tick marks to re-size the ROI. Click and drag on the center of the ROI to re-position. Typical PROSE LR and AP dimensions are 55 mm and 35 mm, respectively.
[+] Next and **[-]** Prior	**[+] and [-]**	Page through the images to determine the extent of the prostate gland.
Start Location	**[Start]**	Find the most inferior slice, click **[Start]**.
End Location	**[End]**	Find the most superior slice, click **[End]**. A typical PROSE SI dimension (voxel thickness) is 30 to 40 mm. If the value is larger, it is difficult to adjust the shim over the entire volume.
SAT Rx	Click the **SAT** icon	Place SAT bands around the prostate to remove signal from fat and from the rectum.
Accept	**[Accept]**	Confirms the voxel position and closes Graphic Rx.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the PROSE acquisition.

PROSE Protocol Example		
What You Select		**Selection Notes**
Scan Operations		
Auto Prescan	**[Auto Prescan]**	Determines and reports the center frequency (CF), the receiver gains (R1 and R2), the transmit gain (TG), gradient shim current offsets (reported as LnWdth in Hz), and the water suppression level. The shim line width for a typical PROSE volume should not exceed 15 Hz. If the value exceeds this limit, check to see if the prescribed volume includes the endo-rectal coil or the rectum.
Spectro Prescan	**[Spectro Prescan]**	The Spectro Prescan is an optional choice that can be used to check on the line width and water and lipid suppression. Experienced users can use the tools on the Spectroscopy window to adjust the shim and improve the line width.
Scan	**[Scan]**	Initiates the acquisition.

Make Prescan Adjustments

Examine the Spectrum

Quick Steps: Examine the Spectrum

1. Click **[Spectro Prescan]** on the Scan Rx Desktop.
2. Check that the **Entry Point** text box value is **`single1`**.
3. Click **[Start]** to acquire a spectrum from the entire PROSE volume.
4. Change the top display window to **Magnitude** and the bottom display window to **Pure Absorp**.
5. If you are using a full phased array coil set, e.g., TORSOPA, you may have to select the endo-rectal coil to see the correct signal.
6. Observe the spectra in the display windows to see if the water peak is near the center of the window. It may be possible to see the metabolite peaks to the right of the water peak.
7. Use the **Zero Order Phase** slider to make the peak in the pure absorption display window look like the magnitude display.

You can use the following steps as a guide to visualize the spectrum acquired from the entire PROSE volume, and, possibly, use the Gradient Shimming control panel to optimize the shim through the volume.

1. Click **[Spectro Prescan]** on the ScanRx Desktop.
2. Check that the **Entry Point** text box value is **`single1`**.
3. Click **[Start]** to acquire a spectrum from the entire PROSE volume.
   - No CSI phase encoding gradients are played out during this acquisition.
4. Change the top display window to **Magnitude** and the bottom display window to **Pure Absorp**.
   - The Waveform Display menu selections are in the first button at the left in the display window control areas.
   - If you have selected an "endo-rectal coil only" coil configuration, e.g., ENDOATD, signals from the endo-rectal coil should be displayed.
5. If you are using a full phased array coil set, e.g., TORSOPA, you may have to select the endo-rectal coil to see the correct signal.
   a) To display the signal from the endo-rectal coil, **Select Options > Display Parameters** from the Spectroscopy window menu bar.
   b) The endo-rectal coil selection is coil 2 for the pelvic/endo-rectal combination and coil 3 for the torso/endo-rectal combination.
      – Signals from the coils are noted as 1, 2, 3, and 4.
   c) Click **[Apply]**.
6. Observe the spectra in the display windows to see if the water peak is near the center of the window. It may be possible to see the metabolite peaks to the right of the water peak.

- You may have to increase the display scale (the up/down arrows below the display windows) in order to observe the metabolite peaks.
- The pure absorption display is the better spectral display, but usually requires a Zero Order Phase adjustment.
- The magnitude display is always positive, but the peaks are broader than the pure absorption peaks and may be distorted.

7. Use the **Zero Order Phase** slider to make the peak in the pure absorption display window look like the magnitude display.
   - It should never be necessary to change the First Order Phase.
   - The baseline should be level on both sides of the water peak.
8. If you see a large lipid resonance that obscures the prostate metabolite resonance peaks, check and correct the placement of the VSS bands to eliminate the unwanted lipid signals.
9. Broad metabolite peaks are indicative of poor homogeneity. If the peaks are too broad, make the recommended checks and adjustments.
   a) Check the position of the PROSE volume relative to the rectum and endo-rectal coil. Reposition the volume as necessary.
   b) Check the locations of the prescribed VSS bands. The VSS bands can be used to suppress signals from regions of high inhomogeneity, i.e., the endo-rectal coil and the rectum.
   c) Manually adjust the X, Y, and Z gradient currents to improve the homogeneity. Refer to the instructions, “Manually Adjust the Homogeneity”.

Quick Steps: Examine the Spectrum, cont.

8. If you see a large lipid resonance that obscures the prostate metabolite resonance peaks, check and correct the placement of the VSS bands to eliminate the unwanted lipid signals.
9. Broad metabolite peaks are indicative of poor homogeneity. If the peaks are too broad, make the recommended checks and adjustments.

Quick Steps: Manually Adjust the Homogeneity

1. Click **[Spectro Prescan]** on the Scan Rx Desktop.
2. Check that the **Entry Point** text box value is **`single1`**.
3. Change the top display window to **Magnitude** and the bottom display window to **Pure Absorp** or **I Chan Raw**.
4. Increase the center frequency by 100 HZ with **Center Freq (AX)**.
5. Click **[Start]** to acquire a spectrum from the entire PROSE volume.
6. Watch the shape and the height of the water peak in both display windows.
7. Record the initial Gradient Shimming values for the X, Y, and Z gradients.
8. Adjust the **Gradient Shimming** sliders, beginning with the Z gradient.
9. Adjust the Y gradient current in ±2 steps.
10. Adjust the X gradient current in ±2 steps.
11. After adjusting the three gradient currents, repeat the adjustments in the same order with a ±1 unit step.

Make Prescan Adjustments

Manually Adjust the Homogeneity

It may be possible to improve the homogeneity through the PROSE volume by manually adjusting the X, Y, and Z gradient currents in the Gradient Shimming area on the Spectroscopy Prescan window. The following steps present an example approach that you may use to manually adjust the shim.

1. Click **[Spectro Prescan]** on the Scan Rx Desktop.
2. Check that the **Entry Point** text box value is **`single1`**.
3. Change the top display window to **Magnitude** and the bottom display window to **Pure Absorp** or **I Chan Raw**.
   - The Waveform Display menu selections are in the first button at the left in the display window control areas.
   - Many spectroscopists prefer to use the **I Chan Raw** display to demonstrate homogeneity changes. In this case, you want the I Chan Raw signal to “ring” out as far as possible.
4. Increase the center frequency by 100 HZ with **Center Freq (AX)**.
   - This change allows you to see an intense water peak in all the display windows. Be sure that you reset the center frequency before leaving the Spectroscopy window.
5. Click **[Start]** to acquire a spectrum from the entire PROSE volume.
6. Watch the shape and the height of the water peak in both display windows.
   - Look for distortions near the base of the water peak displayed in the Pure Absorp display window.
7. Record the initial Gradient Shimming values for the X, Y, and Z gradients.
   - Center the gradient current shim sliders. Use the C button to the left of the sliders. Record the initial shim current values.
8. Adjust the **Gradient Shimming** sliders, beginning with the Z gradient.
   - The sliders have a range of ±10 steps around the center value.

a) Increase the value a +2 steps by moving the slider as far as it will move to the right, while watching the water peak.
   - It takes at least two window display updates to see the effect of a gradient current change.
   - You want the water peak to become narrower, while keeping the bottom of the water peak smooth.

b) If the peak narrows, increase the Z gradient value again by +2 steps.
   - You can re-center the value by clicking **[C]**.

c) Continue to increase the value until the peak starts to distort or fails to narrow.
   - Always return to the last good value.

d) If the peak shape degrades or broadens with a +2 step change, move the slider all the way to the left (a change from the initial value of -2 steps).
   - Remember, you need to wait at least two display updates to see the change.

e) Examine at the line shape.
   - If the shim improves after the -2 step change, decrease the shim current by another 2 steps until the peak stops narrowing or until the shape degrades.

f) Stop at the best shape.

9. Adjust the Y gradient current in ±2 steps.
10. Adjust the X gradient current in ±2 steps.
11. After adjusting the three gradient currents, repeat the adjustments in the same order with a ±1 unit step.

NOTE: The AutoShim results are usually good enough that you can start with ±1 or ±2 unit changes rather than the coarse ±10 unit adjustments. The best procedure is to use a consistent, reproducible method similar to that described above.

12. Once you are satisfied with the spectral line widths and shapes, click **[Done]** to leave the Spectroscopy window.
13. Click **[Scan]**.

Quick Steps: Manually Adjust the Homogeneity, cont.

12. Once you are satisfied with the spectral line widths and shapes, click **[Done]** to leave the Spectroscopy window.
13. Click **[Scan]**.

PROSE Protocol Example

Prescribe the PROSE volume on the axial T2 FSE images. The 3D CSI images are reconstructed on the centers of the T2 FSE images contained within the prescribed PROSE volume if the User CV Scan mode selection equals one.

Table 6-12 provides you with a brief look at an example protocol. The parameters may vary depending on your needs.

Table 6-12 PROSE Protocol Example

Parameter	What You Select
Patient Position	
Patient Position	Supine
Patient Entry	Feet First
Coil	Torso ATDT
Imaging Parameters	
Plane	Oblique
Mode	MRS
Pulse Sequence	PROSE
Grad Mode	Whole
Imaging Options	EDR, SSRF (default)
PSD Name	N/A
Scan Timing	
# of Echoes	1
TE	130
TR	1000
Flip Angle	N/A
Echo Train Length	N/A
Bandwidth	N/S

Parameter	What You Select
Scanning Range	
FOV	11 cm
Voxel Thickness	50 mm
Spacing	6.9 (first selection)
Locs per Slab	8
Acquisition Timing	
Freq	16
Phase	8
NEX	1
Phase FOV	1
Freq DIR	R/L
Auto Center Freq	Water
Autoshim	On
Phase Correct	N/A
User CVs	
Scan mode	1
AWS optimization	0
ROI edge sat mask	7

NOTE: The voxel thickness changes when you prescribe the PROSE volume with the ‘Start” and End” selections on the Graphic Rx screen.

The goal is to select isotropic CSI voxels. With an 11 cm FOV and the 16x8x8 phase encoding matrix selection specified in the prescription in Table 6-12, the isotropic edge dimension is 6.9 mm (i.e., 110/16 = 55/8 = 6.9 mm). The isotrophic dimension is the first selection in the **Spacing** text box.

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Chapter 7

Echo Planar Pulse Sequences

Introduction

Diffusion Tensor Imaging (DTI) is the newest addition to the Echo Planar pulse sequence family. It is used to visualize the white matter fiber tracts in the central nervous system (CNS). DTI provides information on molecular diffusion of biological tissues, such as diffusion anisotropy, principle diffusion direction and the average diffusion coefficient. This information aids a trained physician in monitoring brain development in neonates, in the diagnosis of white matter diseases, and guides surgeons with surgical resection of brain lesions.

This chapter explains the characteristics of the Diffusion Tensor sequence. It also explains the step-by-step instructions to help you learn how to:

- Perform a DTI Sequence
- Launch DTI Processing in FuncTool

In addition, this chapter answers the following questions:

1. What is Diffusion Tensor?
2. Why would you use a Diffusion Tensor pulse sequence?
3. Which imaging options can be used with the Diffusion Tensor pulse sequence?
4. When would you use a Diffusion Tensor pulse sequence?

NOTE: This chapter includes new features or enhancements to EPI sequences. Refer to Volume 2 of the Signa® Infinity with Signa Select™ (ASP2) Learning and Reference Guide (direction #2292262-100) for additional EPI pulse sequences.

What Do I Need to Know About...

This section presents the concepts necessary to successfully understand imaging with the Diffusion Tensor pulse sequence. Specifically, you need to understand:

- Diffusion Tensor Imaging Basics
- Scan Parameters
  - General Parameters
  - User Control Variables
  - Diffusion Options
- Imaging Characteristics
- Associated Imaging Options
- Applications

Diffusion Tensor Imaging Basics

Diffusion Tensor Imaging (DTI) is an imaging technique that produces image contrast proportional to the local diffusion coefficient of water. Both the diffusion coefficient and its directional dependence can be measured using DTI. Data can then be used to image the directional dependence of the local diffusion coefficient in the tissue.

DTI images are acquired on your system but can be post processed through FuncTool to gain additional clinical information. The pulse sequence is an abdaptation of the Diffusion Weighted (DW) single shot Echo Planar Imaging (EPI) sequence (Figure 7-1) for image acquisition. As a refresher, a single shot EPI sequence consists of an initial 90° excitation pulse and 180° radio frequency (RF) pulse. This sequence also incorporates a long enough Repetition Time (TR) period to allow all prescribed echoes, thus filling K-space all at once.

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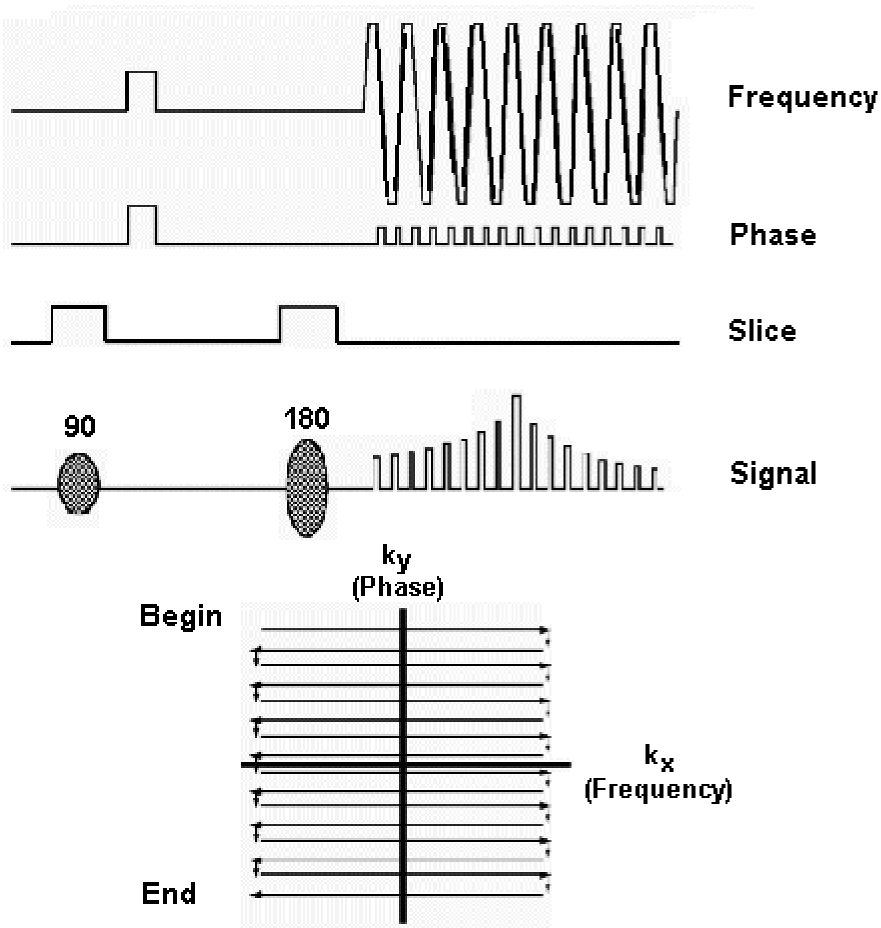
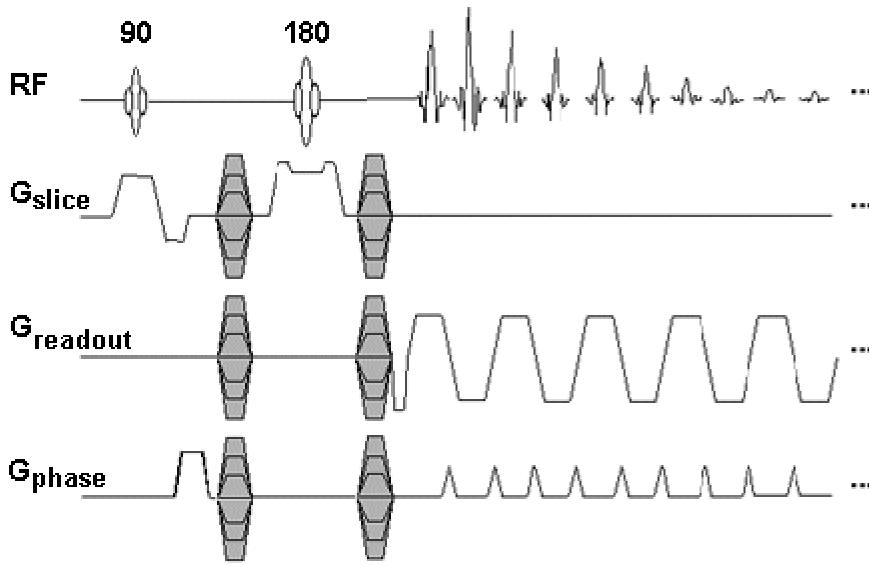
Figure 7-1 Single Shot EPI Pulse Sequence



Like DW single shot EPI, the DTI pulse sequence consists of a 90° excitation pulse and a 180° RF. It also includes a pair of DW gradients, one is placed before the 180° RF, the other immediately after. This pair of gradients is applied not only for the slice gradient axes, but the readout and the phase gradient axes as well (Figure 7-2).

Figure 7-2 DTI Pulse Sequence



These six gradients provide the basis of the mathematical expression called Diffusion Tensor (Equation 7-1). In order to calculate the Diffusion Tensor, at least six diffusion measurements must be performed with diffusion gradients applied along different gradient axes. The true mathematical equation for Diffusion Tensor is shown in Equation 7-1.

Equation 7-1 Diffusion Tensor

$$\mathbf{D} = \begin{bmatrix} D_{xx} & D_{xy} & D_{xz} \\ D_{yx} & D_{yy} & D_{yz} \\ D_{zx} & D_{zy} & D_{zz} \end{bmatrix}$$

DTI creates a set of DW images, as well as T2 weighted images. Both are used to fully characterize the diffusion tensor at each voxel. Based on information derived from the DTI acquisition, an image highlighting white matter tracts can later be produced.

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Scan Parameters

There are several scanning parameters that are important with the DTI pulse sequence. These parameters are responsible for image contrast, signal, and scan time. For easier understanding, the scan parameters are broken down into three main sections:

- General Parameters
- User Control Variables (User CVs)
- Diffusion Options

NOTE: This section only provides the values and information concerning the selection entries that are only relevant to DTI acquisitions.

General Parameters

General parameters are options that are important to acquire MR images. Examples of such options are scan timing parameters and acquisition timing parameters.

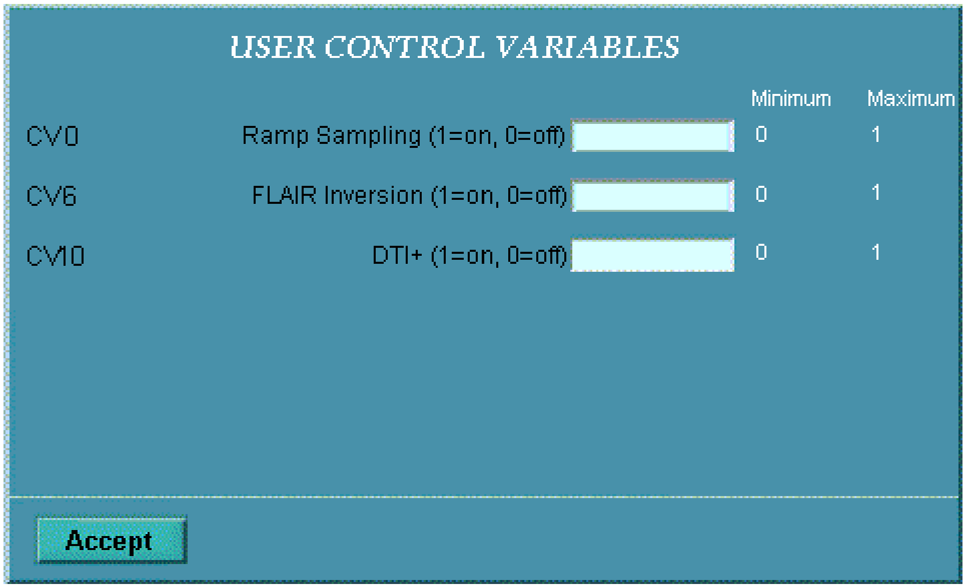
Scan Timing parameters include Echo Time (TE) and Repetition Time (TR). Only a minimum TE is available with DTI. And the TR selection is normally 5000 or more. Increasing the TR increases the amount of available slices. You should select a TR long enough to cover your imaging area within one acquisition.

Acquisition Timing parameters include the frequency matrix, NEX and Phase FOV. In DTI the frequency and phase matrices default to 128, although you can choose a minimum of 64 or a maximum of 256 for both matrices. Scanning with a 128x128 matrix provides adequate resolution in a reasonable amount of scan time.

User Control Variables

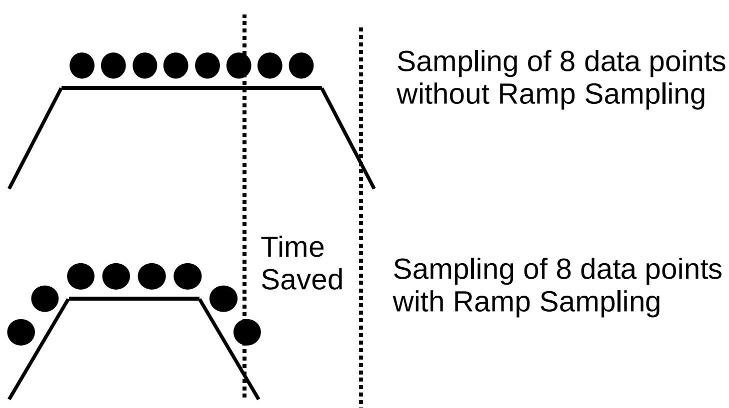
There are potentially three variables displayed on the User CVs Screen (Figure 7-3) that can be used with DTI. The FLAIR Inversion option is displayed on this screen but this option is not compatible with DTI, and is always set to zero.

Figure 7-3 Diffusion Tensor User CVs Screen



Ramp Sampling allows the system to increase the time when the echo is recorded. This is achieved by the system sampling along the ramp-up and ramp-down portions of the frequency gradient, as well as the flat top. The result is shorter Echo Spacing (ES), and the system moves from echo to echo faster. An example of Ramp Sampling is shown in Figure 7-4. The trade-off for using Ramp Sampling, is Receive Bandwidth (RBw) cannot be changed. Typically the system uses a RBw of +/- 62.5 or greater. Remember as RBw increases, SNR decreases. In addition to a high RBw, Ramp Sampling uses the fast receiver during data collection. The fast receiver is not compatible with phased array coils.

Figure 7-4 Effects of Ramp Sampling



The DT1+ CV appears only if your system is a Cardiac Resonance Module (CRM) and has an Advanced Control Gradient Driver (ACGD) configuration.

DTI+ allows you to make maximum use of the gradients. If your system is a CRM and is equipped with ACGD, you can turn on the User CV DTI+ to achieve 50 mT/m gradient performance. If DTI+ is off (set to 0), or your system does not have ACGD, then the peak gradient strength your system can achieve is 40 mT/m.

Diffusion Options

There are 10 options seen on the Diffusion Options screen that are only available with DTI (Figure 7-5). A brief description of each option is provided in Table 7-1.

Figure 7-5 Diffusion Option Screen

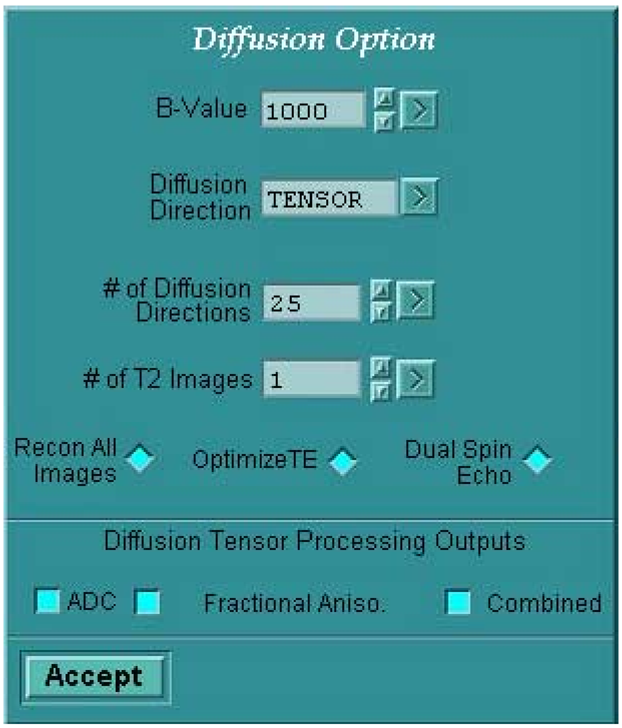
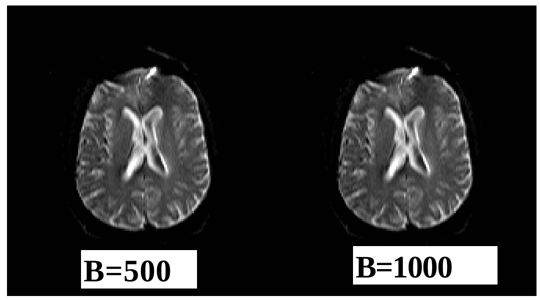


Table 7-1 DTI Diffusion Option Screen

Option	Description
B-value	Indicates the strength and sensitivity of motion probing gradients. As the B-value increases, the sensitivity of the motion probing gradients increases. The maximum B-value for DTI is 3500 s/mm^2, the minimum B-value is 10 s/mm^2.  *Images of Sample B-values 500 and 1000*
Diffusion Direction	For DTI imaging you must select TENSOR, to allow the acquisition to be in tensor mode. Selecting any other direction option is not supported for DTI.
Number of Diffusion Directions	Indicates the number of diffusion directions programmed. The maximum number of diffusion directions is 55, the minimum number is 6. If the number of directions is greater than six, the value must be an odd number. The more directions prescribed, the higher your scan time. If the maximum number of images exceeds 1024, the number of diffusion directions is limited. To achieve a high diffusion direction number, decrease the prescribed number of slices. The recommended number of directions is 25.
Number of T2 Images	Indicates the number of T2 images to be collected at the beginning of the acquisition. The maximum number that can be prescribed is 10, the minimum is 1. The recommended number of T2 images is 1. The more T2 images prescribed, the longer the scan time.
Recon All Images	This radio button defaults to on and is not deselectable.
Optimize TE	Obtains the maximum gradient amplitudes with the minimum possible TE, based on the B-value used. When this option is turned off, B-values are limited and gradient duration is fixed, resulting in a TE of approximately 100 ms. This option defaults to on.

Option	Description (Continued)
Dual Spin Echo	This is an eddy current compensation technique, which reduces distortion. This option increases your TE and decreases SNR. It only produces a single echo.
ADC	A Diffusion Tensor processing output that automatically creates an ADC image data set. This set can be accessed through the Browser as a separate series.
Fractional Anisotropy	A Diffusion Tensor processing output that automatically creates a Fractional Anisotropy image data set. This set can be accessed through the Browser as a separate series.
Combined	A Diffusion Tensor processing output that automatically creates a Combined image data set. This set can be accessed through the Browser as a separate series.

Imaging Characteristics

Diffusion Tensor images are subject to similar image characteristics as conventional DW images. Table 7-2 outlines common parameters and the effects that are seen in DTI images.

Table 7-2 DTI Characteristics

Parameters	Image Effect				
	Echo Spacing	**SNR**	**Resolution**	**Scan Time**	**Geometric Distortion**
Gradient Slew Rate ⇑	⇓	N/A	N/A	N/A	⇓
Receive Bandwidth ⇑	⇓	⇓	N/A	N/A	⇓
Frequency Matrix ⇑	⇑	⇓	⇑	N/A	⇑
Phase Matrix ⇑	N/A	⇓	⇑	N/A	N/A
FOV ⇑	⇓	⇑	⇓	N/A	⇓
Phase FOV ⇑	N/A	⇑	⇓	N/A	⇑
Ramp Sampling ⇑	⇓	N/A	N/A	N/A	⇓
Field Strength ⇑	N/A	⇑	N/A	N/A	⇑
Diffusion Direction ⇑	N/A	N/A	N/A	⇑	N/A
B-Value ⇑	N/A	⇓	N/A	N/A	N/A

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 7-3, the X's indicate the options available for use with the DTI pulse sequence.

Table 7-3 DTI Pulse Sequence Imaging Options

Imaging Options			
X	None	**X**	Variable Bandwidth
	Flow Compensation		No Phase Wrap
	POMP		Extended Dynamic Range*
X	Square Pixel		Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer	**X**	Sequential
X	Cardiac Gating/Triggering**		Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024		ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

NOTE: *Fast receiver is always on, therefore this option is not needed.

**Cardiac Gating/Triggering is only allowed when the slice number is one.

Applications

Currently, DTI is used for brain neuro applications. It is most commonly used for white matter tract visualizations. Visualizing the white matter tracts in the brain can be useful in monitoring patients with stroke, epilepsy, various brain trauma, neonatal brain development, as well as disease management.

How Do I...

This section provides the step-by-step instructions for gaining images visualizing white matter tracts. Specifically, it describes how to:

- Perform a DTI Sequence
- Launch DTI Processing in FuncTool

CAUTION: **Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.**

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Perform a DTI Sequence

DTI allows you to visualize the degree of diffusion anisotropy in brain tissue. Refer to the Applications section within this chapter for specific applications for DTI sequences.

Use this procedure to set-up and scan a DTI imaging pulse sequence. Afterwards additional images may be displayed using the FuncTool software located on your Advantage Workstation (AW) system.

1. Enter the Patient Information.
   - Located on the Scan Rx Desktop.
2. Acquire a valid 3-Plane Localizer series.
   - Make sure the localizer covers the whole brain.
3. Click **[New Series]**.
4. Select **Coil > Head**.
   - DTI is only compatible with head imaging.
5. Select **Plane > Oblique**.
   - DTI is compatible with any scan plane.
6. Select **Mode > 2D**.
   - DTI is only compatible with 2D imaging mode.
7. Select the **DW - EPI** pulse sequence.
   - Enables you to perform DTI acquisition.
8. Select **Grad Mode > Zoom**, if applicable.
   - This optimizes gradient amplitude and slew rates over small regions of interest for Twin*Speed*™ Resonance Module (TRM) systems.
9. Click the **DWI Screen** icon.
   - Located in Additional Parameters area.
10. Enter your desired B-value.
    - Recommended B-value is 1000.
11. Select **Tensor** for the Diffusion Direction.
    - Located in the Diffusion Option window.

Quick Steps: Perform a DTI Sequence

1. Enter the Patient Information.
2. Acquire a valid 3-Plane Localizer series.
3. Click **[New Series]**.
4. Select **Coil > Head**.
5. Select **Plane > Oblique**.
6. Select **Mode > 2D**.
7. Select the **DW - EPI** pulse sequence.
8. Select **Grad Mode > Zoom**, if applicable.
9. Click the **DWI Screen** icon.
10. Enter your desired B-value.
11. Select **Tensor** for the Diffusion Direction.
12. Enter the number of directions in the **# of Diffusion Directions** text box.
13. Enter your desired number of T2 images.
14. Turn on all remaining options in the Diffusion Option window.
15. Click **[Accept]**.
16. Click the **User CVs** icon.
17. Select the desired options for this sequence.
18. Click **[Accept]**.

Quick Steps: Perform a DTI Sequence cont.

19. Enter the **Scan Timing** parameters.
20. Enter the **Scanning Range** parameters.
21. Enter the **Acquisition Timing** parameters.
22. Click the **Graphic Rx** Icon.
23. Click and drag on the image to deposit scan prescription slices.
24. Click **[Accept]**.
25. Click **[Save Series]**.
26. Click **[Prepare to Scan]**.
27. Click **[Scan]**.

12. Enter the number of directions in the **# of Diffusion Directions** text box.
    - Recommended value is 25.
13. Enter your desired number of T2 images.
    - Recommended value is 1.
14. Turn on all remaining options in the Diffusion Option window.
    - All options can be used simultaneously or in any combination.
    - For additional information on the remaining options in this window refer to the DWI Screen section of this chapter.
15. Click **[Accept]**.
    - This registers all selections into the current acquisition.
16. Click the **User CVs** icon.
    - Located in the Additional Parameters area.
17. Select the desired options for this sequence.
    - Ramp Sampling is required for this sequence.
    - FLAIR is not compatible with Tensor Imaging.
    - DTI+ is only available if your system is equipped with ACGD.
18. Click **[Accept]**.
    - This registers all selections into the current acquisition.
19. Enter the **Scan Timing** parameters.
    - The only allowable number of shots is 1.
    - The only allowable TE is minimum.
    - Recommended TR is 5000 or more. This ensures all slices being acquired in one acquisition.
20. Enter the **Scanning Range** parameters.
    - Recommended FOV is 26.
    - Recommended Slice Thickness is 5.
    - Recommended Spacing is 1.5.

21. Enter the **Acquisition Timing** parameters.
    - Recommended matrices is 128x128.
    - Recommended NEX and Phase FOV is 1.
22. Click the **Graphic Rx** Icon.
    - Located in the Additional Parameters area.
23. Click and drag on the image to deposit scan prescription slices.
    - Axial plane slices are the only slices compatible with DTI pulse sequences.
    - Slices should cover the whole brain.
24. Click **[Accept]**.
    - This registers slice locations into current acquisition.
    - Location values are displayed in the Scanning Range area.
25. Click **[Save Series]**.
    - This closes the current prescription screen.
26. Click **[Prepare to Scan]**.
    - Downloads DTI acquisition.
27. Click **[Scan]**.
    - Initiates your DTI acquisition.

Launch DTI Processing in FuncTool

Quick Steps: Launch DTI Processing in FuncTool

1. Select the DTI series from the (AW) Browser.
2. Click **[FuncTool]**.
3. Click **[OK]** to dismiss the message.
4. Select **Diffusion** from the list of protocols.
5. Follow the directions in the on-screen guide to generate your desired functional maps.

In order to generate additional functional data for your DTI images, use the Functool software loaded on your Advantage Workstation (AW).

Use this procedure to launch DTI processing in FuncTool.

1. Select the DTI series from the (AW) Browser.
2. Click **[FuncTool]**.
   - A message box indicates this is not a time course series.
3. Click **[OK]** to dismiss the message.
4. Select **Diffusion** from the list of protocols.
5. Follow the directions in the on-screen guide to generate your desired functional maps.

NOTE: Functool is not needed to show images as three different maps can be automatically reconstructed on your Signa system. The maps that can be generated on your system are an ADC, Fractional Anisotropy, and the Combined maps.

Refer to the Functional Analysis manual for additional information on how to launch a protocol.

Chapter 8

Functional Magnetic Resonance Imaging

Introduction

Functional Magnetic Resonance Imaging (fMRI) is an optional brain mapping software technique that incorporates Blood Oxygen Level Dependent (BOLD) imaging to map task activated regions in the brain. This type of imaging aids trained physicians in surgical planning and monitoring, as well as during the observation of post surgery patients.

Functional MRI Imaging operates on two software platforms: BrainWave and BrainWaveSO (BrainWave Software Only). The BrainWaveSO platform does not include the stimulus devices like the BrainWave platform. Differences that occur between the platforms are noted in the text.

This chapter explains the characteristics of an fMRI examination. It also provides the step-by-step instructions to help you learn how to:

- Set Up the Visual Equipment (BrainWave only)
- Perform an fMRI Exam
- Reprocess fMRI Data
- Import fMRI Data
- Save/Restore BrainWaveSO System Information
- Print Color Images
- Delete Logfiles

In addition, this chapter answers the following questions:

1. What is brain mapping?
2. What is BOLD imaging?
3. When would you perform an fMRI exam?
4. What are five types of paradigms?

What Do I Need to Know About...

This section presents the concepts necessary to successfully understand fMRI. Specifically, you need to understand:

- fMRI Description
- BOLD Technique
  - User Control Variables
- Sensory Equipment BrainWaveSO
- Sensory Equipment BrainWave
- BrainWaveSO Paradigms
- BrainWave Paradigms
  - Voluntary Hand Movement
  - Passive Listening
  - Verb Generation
  - Rhyming
  - Semantic Decision
- BrainWave/BrainWaveSO Software
  - Acquire fMRI Scans Window
  - Visualize Maps Window
  - Re-Process fMRI Scans Window
  - Manage System Window

fMRI Description

Functional Magnetic Resonance Imaging consists of a Single Shot-Gradient Echo Echo Planar Imaging (SS-GRE EPI) pulse sequence used in conjunction with clinical paradigms to visualize signal intensity changes during task activation. The BrainWave software, located on your Advantage Windows (AW) workstation, is also used to accomplish this type of exam. With these three key elements working simultaneously, images are produced and post processed into color maps. The color maps display the intensity levels where task activation has occurred. The final product is commonly known as Brain Mapping.

BOLD Technique

The BOLD technique is the brain mapping process that records signal intensities in active regions of the brain. In BOLD fMRI, the signal increases during activation due to an oversupply of oxygenated blood in the capillaries. BOLD uses the magnetic susceptibility differences between these blood oxygenation states. This technique consists of acquiring a SS-GRE EPI acquisition, lasting approximately 6 minutes and 40 seconds. During this time, your patient performs a pre-determined task, called a paradigm. The paradigm is performed for 24 seconds, followed by a 24 second rest period. This task and rest (sometimes called task 'on', task 'off') procedure is repeated for eight cycles. As your patient performs the defined task, the blood oxygen levels in the brain increase and are seen on images as signal intensity changes. For fMRI, tasks are usually performed with the aid of various sensory equipment.

User Control Variables

Functional MRI uses a modified version of the SS-GRE EPI pulse sequence. The sequence is acquired in the same manner as a conventional SS-GRE EPI sequence, allowing only a 64x64 matrix and providing a number of User Control Variables (CVs). Figure 8-1 displays the User CVs window and Table 8-1 lists a brief description of each variable.

Figure 8-1 SS-GRE EPI User CVs

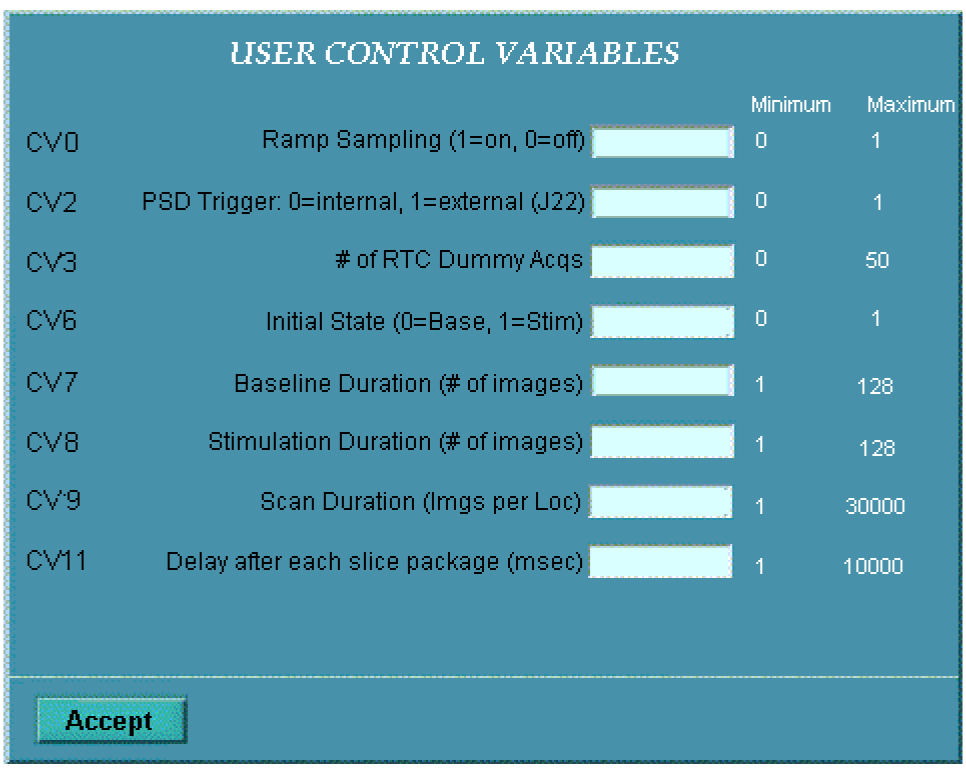


Table 8-1 SS-GRE EPI User CVs

User CVs	Description
Ramp Sampling	Indicates the acquisition of echoes during the rise and fall times of the gradient slope. A 1 turns it ON and 0 turns it OFF.
PSD Trigger	For research sites only. Use this feature if your site has a separate triggering device. The system default, 0, indicates internal triggering and 1 indicates external triggering.
# of RTC Dummy Acqs	Indicates the number of discarded images. The discarded images are acquired during the initial rest period of your fMRI acquisition. The acceptable number of images, which can be discarded, is 0 to 50. The default number of dummy acquisitions for BrainWave is 4.
Initial State	Indicates the starting preference phase for the fMRI acquisition. Use 0 for starting during the resting phase (baseline). Use 1 for starting during the active phase (stimulation).
Baseline Duration	Indicates the number of images recorded during the resting phase. The range of images is 1 to 128.
Stimulation Duration	Indicates the number of images recorded during the active phase. The range of images is 1 to 128.
Scan Duration	Indicates the number of images acquired per location. The range of images is 1 to 1000.
Delay after each slice package	Indicates the time delay between each location phase. The time delay ranges from 1 to 1000 milliseconds (msec).

Sensory Equipment BrainWaveSO

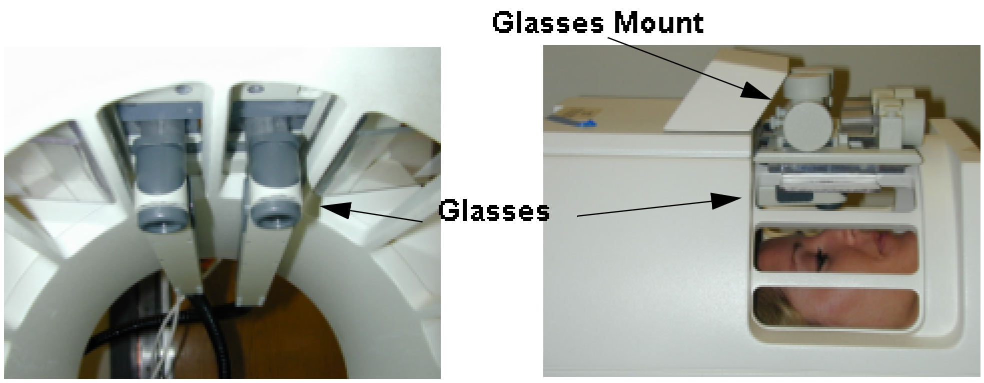
This section does not apply if your system is operating BrainWaveSO software rather than BrainWave software. Read the operator documentation provided by the manufacturer of your stimulus device.

Sensory Equipment BrainWave

There are several pieces of sensory equipment used to perform fMRI: earphones, glasses, hand controls, and a microphone. This equipment provides the visual or audio stimulus delivery and recording mechanisms. The sensory equipment used in the exam usually depends on which paradigm is being applied.

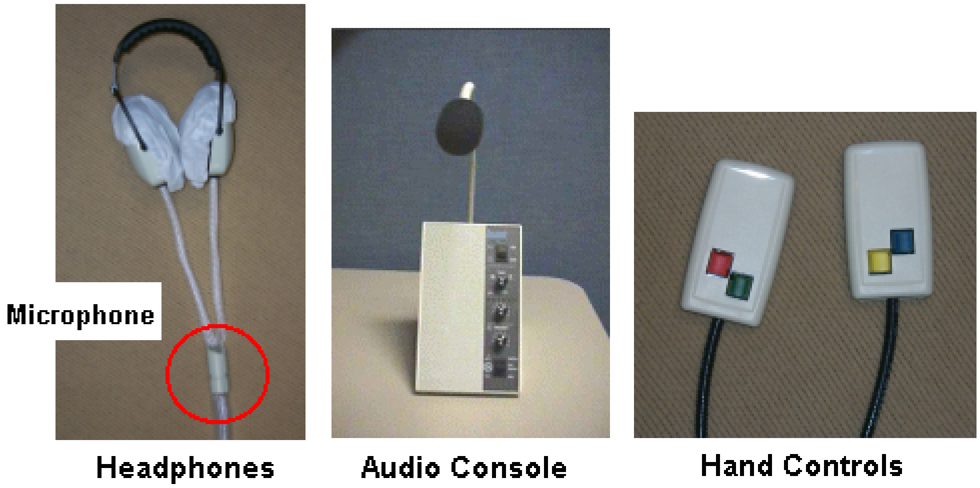
The visual equipment includes a pair of glasses and a holder, which is attached to the head coil (Figure 8-2). The glasses allow your patients to see the visual stimulus without having to move their head. The visual stimulus displays as shapes or words.

Figure 8-2 Visual Equipment



The audio equipment includes a pair of earphones and a microphone attached to the audio console (Figure 8-3). The earphones allow your patient to hear the audio paradigms. The audio console resides on your operator console and is used to select the sound medium and allows you to communicate with your patient. The sound volume control is located on the front side of the audio console. The back side of the auto console includes two identical switches. Both need to be set in functional or clinical modes. Clinical mode permits mono sound and allows the volume to be controlled through the audio console. Functional mode permits stereo sound and allows the volume to be controlled through the Stimulus PC.

Figure 8-3 Audio Equipment



Stimulus response equipment includes a pair of hand controls (Figure 8-3). They are designed to record your patient's response to various stimuli. The right-hand control has blue and yellow push buttons and the left-hand control has green and red push buttons.

BrainWaveSO Paradigms

Since BrainWaveSO has no direct connection to, or knowledge of the sensory equipment being used, the paradigm information consists solely of an assigned paradigm name. The assigned name is permanently associated with the resulting data sets and used for image annotation purposes. Refer to the BrainWave/BrainWaveSO Software section in this chapter for information about entering your own paradigms.

BrainWave Paradigms

Paradigms are task activation procedures. Instruct your patient before the exam on which paradigm to perform during the activation and control periods. Six paradigms are available for fMRI, however, only one paradigm can be performed per acquisition.

- Voluntary Hand Movement (left or right hand)
- Passive Listening
- Verb Generation
- Rhyming
- Semantic Decision
- Calibration Training

It is necessary to prepare your patient for each paradigm. Suggestions of what you might say to prepare your patient are given in the Patient Preparation section of each paradigm.

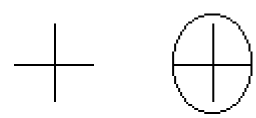
NOTE: The following paradigms are only for systems that are running BrainWave software. If your system is operating BrainWaveSO, refer to your manufacturer's guidelines for building a paradigm.

Voluntary Hand Movement

There are two paradigms associated with Voluntary Hand Movement: Left Hand Movement and Right Hand Movement. Each paradigm results in a task that produces signal intensity changes in various parts of the motor system, such as the supplementary motor area (SMA), contralateral primary motor cortex, cingulate motor area, and ipsilateral cerebellar cortex.

During this paradigm, your patient sees a cross-hair through the glasses, which periodically appears surrounded by a circle (Figure 8-4). This circle appears at the rate of once per second. Every time your patient sees the circle, either the left or right button is pressed depending on which hand movement paradigm is selected. If your patient presses both buttons when the circle appears, the response is counted as an error.

Figure 8-4 Illustration of Voluntary Hand Movement Paradigm



Patient Preparation

Here is an example of how you can prepare your patient to perform the Right Hand Movement paradigm.

> "Hold the boxes in both your hands. Look into the glasses. You should see a cross-hair. Keep your eyes on the cross-hair. Whenever you see a circle appear around the cross-hair, press only the right button once. If no circle is seen around the cross-hair, do not press any buttons. Try to keep your head as still as possible throughout the scan."

NOTE: When performing Left Hand Movement paradigm, substitute the left button for the right button in the above example.

Passive Listening

The Passive Listening paradigm is the easiest of all the paradigms. It produces and records signal intensity changes in Wernicke's area, which represents the receptive language area. This paradigm only requires the patient to listen.

During this paradigm, your patient wears headphones and listens to a narration of English text for 24 seconds. For the next 24 seconds, your patient hears gibberish, which is the English narration played backwards. While the narration is playing, your patient should lie still and carefully listen. You should not tell your patient what is happening, nor should they try to make any sense of it.

Patient Preparation

Here is an example of how you can prepare your patient to perform the Passive Listening paradigm.

> "For this test, all you need to do is to hold your head still and carefully listen as the recording plays. Do not try to understand the gibberish, because it will not make any sense."

Verb Generation

The Verb Generation paradigm produces and records signal intensity changes in Broca's (Brodmann's 45) area of the brain, which represents expressive language.

During this paradigm, your patient sees words in the form of nouns through the glasses. Your patient should think of an action word, in the form of a verb associated with the word seen. It is important to tell your patient not to say the words aloud, only think the words.

Patient Preparation

Here is an example of how you can prepare your patient to perform the Verb Generation paradigm.

> "For this test it is very important you lie still. Through these glasses you should see a cross-hair. While looking at the cross-hair, try not to think of anything. When the cross-hair disappears, it is replaced by a word. Try to think of an action word associated with the word. For example, if you see the word 'book,' you might think of the word 'read.' It is important that you only think the word silently and NOT say the word out loud. A new word appears

```
every few seconds. Remember to silently think of the
action words."
```

Rhyming

The Rhyming paradigm is designed to produce signal changes in the areas of the brain responsible for phonologic processing. These areas of brain activation are similar to those areas activated by the Verb Generation paradigm, although the Rhyming paradigm activated areas are more specific.

NOTE: This is a difficult task to perform. Not all patients are able to effectively complete this task.

During this paradigm, your patient sees two words in the glasses. If the two words rhyme, your patient presses the right button. If the two words do not rhyme, your patient presses the left button. Your patient should only press one button per word pair. Pressing both buttons at the same time is counted by the system as an error.

Your patient also sees two rows of five sticks and determines whether the two rows are identical. If the two rows are identical, your patient presses the right button. If the rows are not identical, the left button is pressed. The button needs to only be pressed once to make a selection.

Patient Preparation

Here is an example of how you can prepare your patient to perform the Rhyming paradigm.

```
"For this test, it is important to keep your head
very still. Hold the controls in both hands and look
into the glasses. At times, you will see a pair of
words, which changes every few seconds. Whenever you
see a pair of words that rhyme, press the right
button once. If the words do not rhyme, press the
left button once. Remember, the right button is for
rhyming words.

At other times during this test, you will see two
rows of five sticks. Whenever the rows of sticks look
identical, press the right button once. If the rows
are not identical, press the left button once.
Sometimes the differences are subtle, so look
carefully. Both the words and the sticks change every
few seconds."
```

Semantic Decision

The Semantic Decision paradigm is the most challenging of all previously mentioned paradigms. It is sometimes called the animal paradigm and is designed to produce signal intensity changes in the areas of the brain responsible for semantic processing.

NOTE: This is a fairly difficult task to perform. Not all patients are able to effectively complete this task.

During this paradigm, your patient hears the names of various animals. If the animal is both native to the United States and commonly used by humans, your patient presses the right button. Animal characteristics include animals used for hunting, as a pet, or for domestic purposes. It excludes zoo-kept animals. If the animal is not native to the United States or is not commonly used by humans, the left button is pressed. If both buttons are pressed, the system records the response as an error.

At other times during this test, your patient hears a series of tones or beeps, each lasting approximately one second. If exactly two tones are heard during the series, your patient presses the right button once. If more or less than two tones are heard during the series, your patient presses the left button once.

Patient Preparation

Here is an example of how you can prepare your patient to perform the Semantic Decision paradigm. Make sure you allow enough time to thoroughly prepare your patient for this test, as the tasks are more challenging than any other paradigm.

> "For this test, hold the controls in both hands and look into glasses. You should see cross-hairs in the glasses but nothing else appears. Through your headphones, you sometimes hear the names of animals. Whenever you hear the name of an animal that is both commonly used by humans and a native to the United States, press the right button once. If this animal is not common to the United States or not used by humans, press the left button once. You will hear the names of new animals every few seconds.
>
> At other times during this test, you will hear a series of beeps. Whenever you hear a set of beeps that contains exactly two tones, press the right button once. If more or less than two beeps are heard, press the left button once. You will hear a new series of beeps every few seconds. Keep your eyes fixed on the cross-hairs and remember to hold your head as still as possible throughout the scan."

Calibration Training

The Calibration Training paradigm is a testing paradigm. It can be used to help prepare your patient for an fMRI procedure, and to verify the paradigm delivery system is functioning properly. Alphabets are displayed through the glasses and an audio sound sample is transmitted through the headphones.

BrainWave/BrainWaveSO Software

BrainWave™ is the brain mapping software on the AW system used to record the data acquired during an fMRI exam. It integrates the sensor device with the software. BrainWaveSO is the same brain mapping software with the same applications as BrainWave except it does not include integrated sensor device information.

How can you tell if your system is operating BrainWave versus BrainwaveSO software? The button on the AW Browser is labeled either BrainWave or BrainWaveSO. In addition, the menu titles display either BrainWave or BrainWaveSO.

This software is used to start your functional brain acquisition and visualize brain maps. The BrainWave software is divided into four main windows, which can be accessed from the Main Menu (Figure 8-5).

- Acquire fMRI Scans
- Visualize Maps
- Re-Process fMRI Scans
- Manage System

Each window is equipped with several functions, as well as the BrainWave or BrainWaveSO Message and Warning text areas. The BrainWave Message area displays information regarding the system status. For example, the system may display messages such as, “BrainWave is in idle mode” or “BrainWave is now importing data to the AW Browser.” The top of the message area always displays the software version. The Warnings area displays information regarding when the system is not responding normally. For example, the system may display a message such as, “BrainWave is unable to import data to AW Browser.” After a warning has been posted, you should check to see if the problem can easily be resolved or contact your service engineer to correct the problem.

Figure 8-5 BrainWave Main Menu

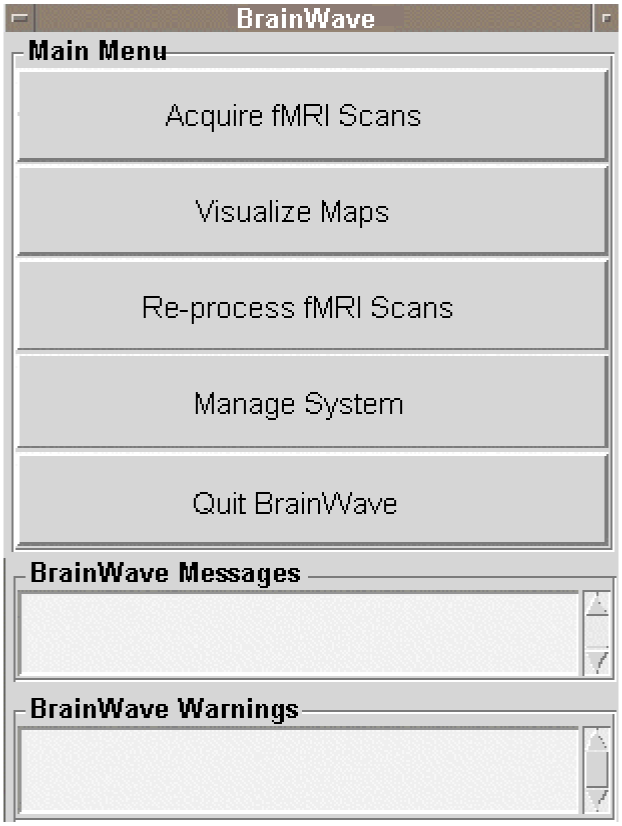


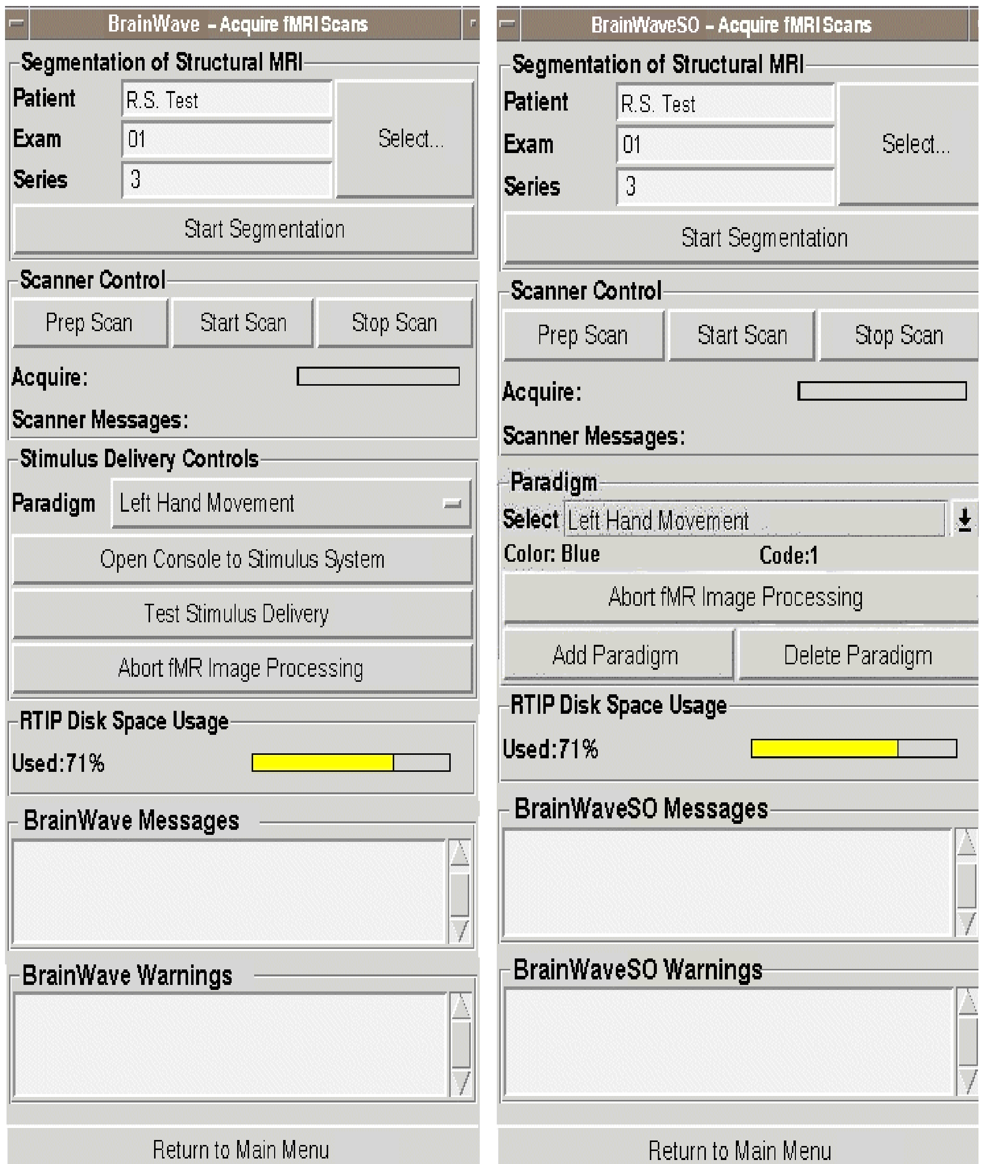
Table 8-2 provides a description of the selections in the BrainWave Main Menu.

Table 8-2 BrainWave Main Menu Selections

Selection	Description
[Acquire fMRI Scans]	Opens the Acquire fMRI Scans window, providing the functions for collecting and delivering paradigm fMRI data.
[Visualize Maps]	Opens the Visualize Maps window, providing the functions for displaying images with overlying color maps.
[Re-Process fMRI Scans]	Opens the Re-Process fMRI Scans window, providing the functions for re-analyzing fMRI data, processing fMRI data, and re-importing images from the AW system.
[Manage System]	Opens the Manage System window, providing options for setting system modes and establishing and modifying configuration system defaults.
[Quit BrainWave]	Exits the BrainWave software.

Acquire fMRI Scans Window

Figure 8-6 BrainWave Acquire Window (left) and BrainWaveSO Acquire Window (right)



There are three main functions in the Acquire fMRI Scans window:

- Segmentation Process
- Scanner Control
- Stimulus Delivery

On your MR system, you must enter all of the imaging parameters before acquiring the fMRI data. When completed, use the Acquire fMRI Scans window to prepare and start the scan. Table 8-3 provides a description of the functions in this window.

Table 8-3 Acquire fMRI Scans Selections

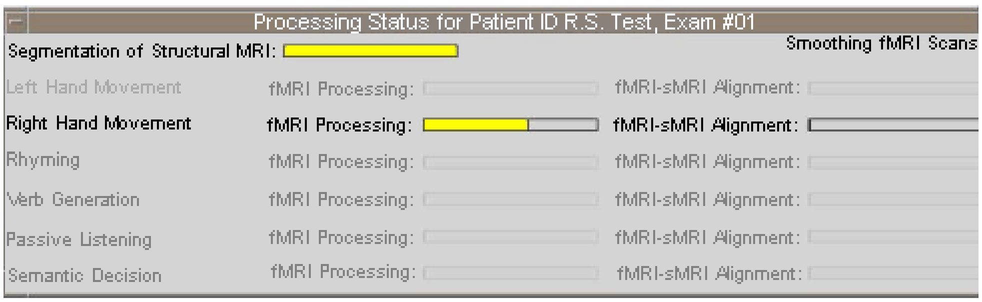
Selection	Description
Segmentation of Structural MRI Area	
Patient	Displays the patient identification (ID) number.
Exam	Displays the patient exam number.
Series	Displays the patient series number.
[Select]	Opens the Browser for selection of the correct patient, exam, and series for segmentation. It also allows you the choice to perform structural scans both before and after activation scans.
[Start Segmentation] or [Abort Segmentation]	Starts or stops the segmentation process, which automatically extracts the skin and bone data from your selected 3D series. The **[Abort Segmentation]** button is only seen if the segmentation process has begun.
Scanner Control Area	
[Prep Scan]	Prescans the fMRI series. Also creates your EPI reference scan for the fMRI series you prescribed on your MR system.
[Start Scan]	Begins the fMRI acquisition.
[Stop Scan]	Aborts the fMRI acquisition.
Acquire	Provides a quick view of the completion percentage of the acquire phase of your scan.
Scanner Messages	Displays messages, regarding scanner status, posted in your MR scanner Message window.

Selection	Description (Continued)
Stimulus Delivery Controls Area	
Paradigm	Opens the Paradigm selection menu, which displays a list of all the paradigms you can perform on your patient. Refer to the BrainWave Paradigms section of this chapter for additional information. **Only with BrainWaveSO** The color and code number associated with the paradigm when using Composite Z-Map display mode is displayed above the **[Abort fMRI Image Processing]** button. The code number has a 1:1 correspondence with the paradigm name. Each paradigm name should always be unique. Never overwrite a paradigm for which scan data already exists.
Add Paradigm	**Only with BrainWaveSO** Opens a pop-up window that allows you to add a paradigm name to the list of paradigms, as well as the associated color when Composite Z-Map mode is used for BrainWave Visualization.
Delete Paradigm	**Only with BrainWaveSO** After a paradigm is selected from the Paradigm list and then Delete Paradigm is selected a Delete window opens allowing removal of the paradigm.
[Open Console to Stimulus System] or [Close Console to Stimulus System]	**Only with BrainWave** Opens and closes the Stimulus window on the personal computer (PC). Allows you to view the Stimulus computer and verify the stimulus is being delivered. The **[Close Console to Stimulus System]** button is only seen if the stimulus system has been opened.
[Test Stimulus Delivery] or [Abort Stimulus Delivery]	**Only with BrainWave** Allows you to perform a test of the paradigm stimulus you wish to give to your patient, without starting your fMRI acquisition. The **[Abort Stimulus Delivery]** button is only seen while the stimulus test is being delivered.
[Abort fMR Image Processing]	Stops any active image processing function. This includes fMRI image processing/analysis and alignment of fMRI data to the structural data. It does not stop visualization or image displays.
RTIP Disk Space Usage Area	
Used	Provides a quick view of the percentage of RealTime disk space used.
[Return to Main Menu]	Closes the Acquire fMRI Scans window. Displays all the Main Menu functions.

Segmentation of Structural MRI Area

Segmentation is the process of automatically removing the outer layers of tissues for a 3D volume study. The end result is a 3D volume with the brain free of skin or skull tissues. The segmentation process is initiated with the **[Start Segmentation]** button. Once the 3D SPoiled Gradient Echo (SPGR) volume has been acquired and reconstructed on your MR system, the images are transferred to your AW and the segmentation process begins. A Processing Status window (Figure 8-7) displays the completion status of the segmentation process. After the segmentation process is complete, the results are automatically transferred and stored on the AW database.

Figure 8-7 Processing Status Window



The fMRI Processing bar represents the processing of the activation data. When the processing is finished, the following data is displayed in the AW Browser, which means that it can be saved and restored as DICOM information.

- The Mean EPI data, which is the size of the acquisition matrix.
- The Big Mean EPI data, which is the size of the structural data. This is the data that is selected when visualizing maps. It is selected by clicking the **[Average EPI]** button from the Paradigm pull-down menu on the Visualize Map window.
- The Z-map, which is the statistical data that is the result of the activation processing on the acquired matrix.
- The Big Z-map, which is the statistical data that is the result of the activation processing on a larger matrix.

The Alignment progress bar represents aligning the activation results to the segmented data (anatomy images minus the skull and skin). When the processing is finished, the B.I.P. (Burned in Pixel) data is displayed in the AW Browser, which means that it can be saved and restored as DICOM information.

Scanner Control Area

The Scanner Control area is used to prepare, start, and stop the fMRI acquisition. On the AW, you use the **[Prep Scan]** button to switch your MR system into scan mode, perform the Auto Prescan and EPI Reference Scan, and create a template image. Once the acquisition is prepared, it can be started and stopped. The Acquire status meter allows you to visualize a percentage of how much of your fMRI series has been completed.

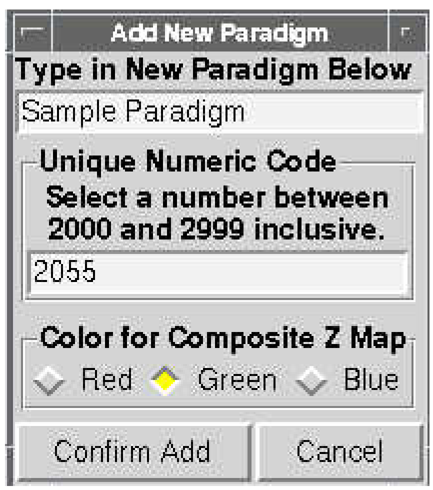
Stimulus Delivery Controls Area

In the Stimulus Delivery Controls area, you use the **[Paradigm]** button to select the paradigm you want to perform.

NOTE: Refer to the BrainWave Paradigms section in this chapter for additional information.

If your system is operating BrainWaveSO software, you can add or delete a paradigm from the Acquire fMRI window. Clicking the **[Add Paradigm]** button opens the window in Figure 8-8. This window only appears with BrainWaveSO.

Figure 8-8 Add Paradigm Window



The first 15 characters of the text string entered in the text box is stored with the RTC data during acquisition. The full string of characters is stored in the series description in the AW Browser and appears on the image annotation. Enter a different name for each paradigm. The text you enter can be longer than 15 characters, just make sure the first 15 characters are unique.

The code is a 1:1 correspondence with the name. Once you name a paradigm and then acquire scans with the paradigm, never re-use the paradigm name. Always create a new name and code.

For example, in Table 8-4, the first 15 characters are the same in the left column of the table (incorrect), where the first 15 characters are unique in right column of the table (correct).

Table 8-4 Text Names

Incorrect Text Name	Correct Text Name
Visual Stimulation Green	Visual Stim Green
Visual Stimulation Red	Visual Stim Red

The color selection is used for the associated paradigm when using Composite Z-Map display mode in BrainWave Visualizer. Composite Z-Map mode allows simultaneous display of multiple paradigms on one image with variation in the colors used to identify the separate paradigms (refer to the Visualize fMRI Data chapter of this guide).

After a paradigm is selected from the Paradigm Selection pull-down menu, and the **[Delete Paradigm]** button is clicked, a confirmation window opens (Figure 8-9). This window only appears with BrainWaveSO.

Figure 8-9 Delete Paradigm Window

Use the **[Test Stimulus Delivery]** button to verify the Stimulus software is operating properly or to allow your patient to see a sample of the stimulus about to be delivered. A sample of the selected paradigm stimulus is displayed without starting the fMRI acquisition. You can use the **[Open Console to Stimulus System]** button to see how your patient is responding to the stimulus being given. Once open, two separate windows are seen: the Patient Responses window (Figure 8-10) and the Motion Detection (Figure 8-11) window.

NOTE: During the actual fMRI scan, it is not recommended to have the Stimulus system open. Updates to this window require the use of the systems working memory and may interfere with BrainWave functioning.

You can print a paper copy of the Patient Responses and Motion Detection graphs with the **[Print Plot]** button located in the bottom right of the window. Printing only includes your patient's graph. This does not include the text in the lower left corner of each window.

NOTE: If a plot is desired, it must be printed before beginning another paradigm. Additional paradigms generate new plots and replace all existing plots. Previous paradigm plots can not be regenerated.

The text in the lower left corner of the Patient Responses window provides a summary of how well your patient performed the given stimuli. For example, the Patient Responses window in Figure 8-10 shows the patient responded to 79.17% of all stimuli in the latest block, with 94.74% accuracy. The text information is updated whenever the stimuli switches from a control block to a task block or vice versa. Figure 8-10 only appears with the BrainWave software and not with BrainWaveSO software.

Figure 8-10 Patient Responses Window

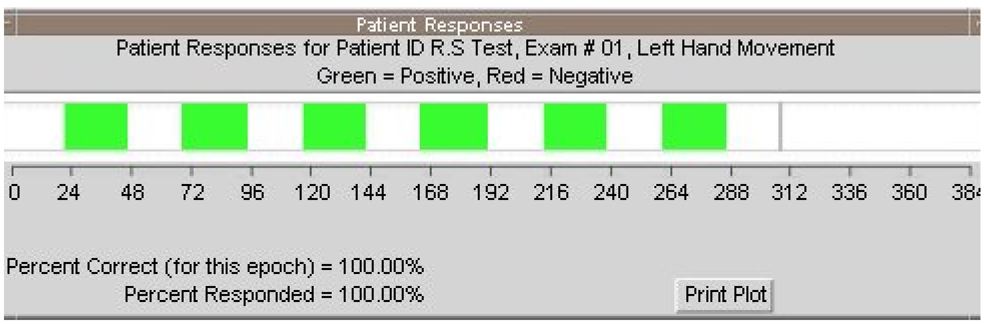
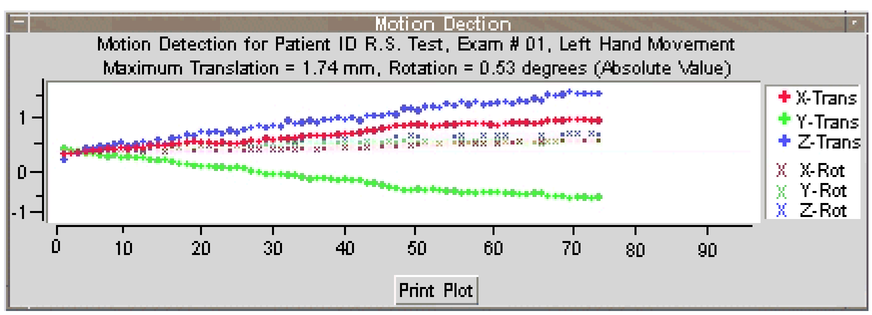


Figure 8-11 Motion Detection Window



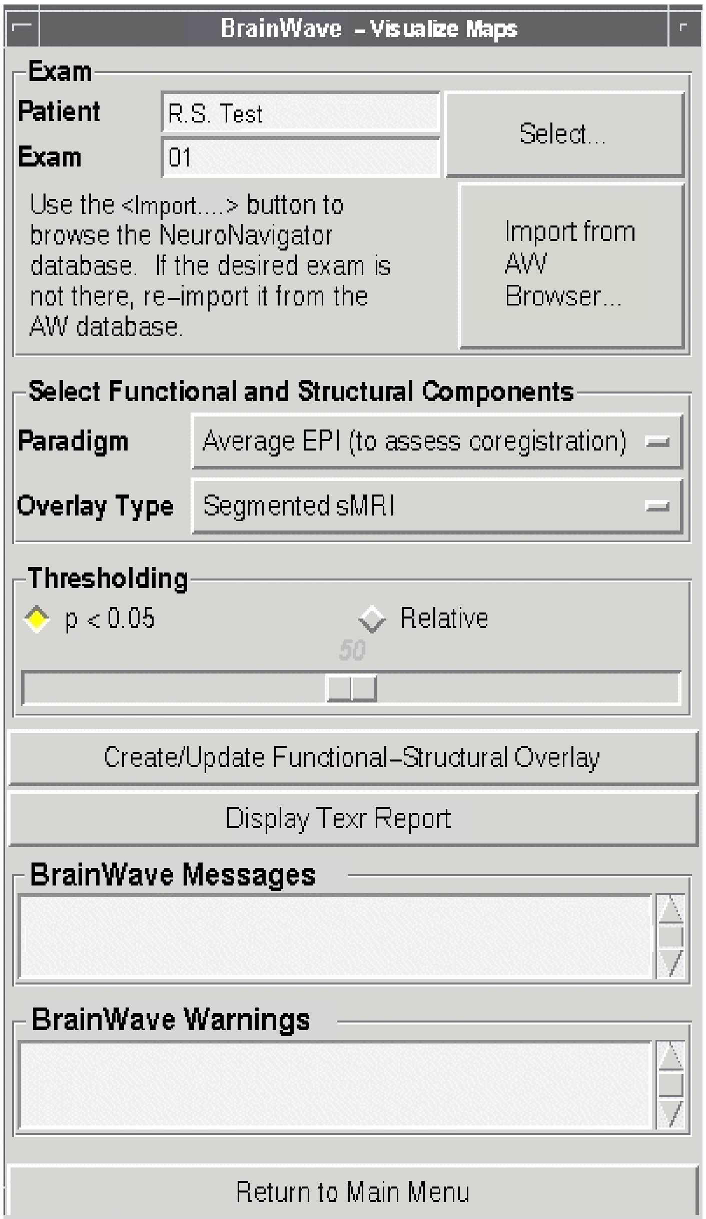
After the acquisition of the fMRI scan, the BrainWave software automatically starts analyzing and processing the data. You can stop the analyzing and processing, if needed, with the **[Abort fMR Image Processing]** button. You can resume the process at a later time from the Re-Process fMRI Scans window.

NOTE: Refer to the Re-Process fMRI Scans Window section of this chapter for additional information regarding restarting the analyzing and processing functions.

Visualize Maps Window

BrainWave has a visualization data tool responsible for displaying images with overlying color maps. You use the Visualize Maps window (Figure 8-12) to make your selections.

Figure 8-12 Visualize Maps Window



The Visualize Maps window has two main functions: displaying functional data overlays and displaying the Text Report.

Table 8-5 provides a description of the selections in this window.

Table 8-5 Visualize Maps Window Selections

Selection	Description
Exam Area	
Patient	Displays the patient ID number.
Exam	Displays the patient exam number.
[Select]	Opens the BrainWave Browser database for patient selection.
[Import from AW Browser]	Opens to the AW archived database and allows you to reimport your desired patient and exam from the archived database.
Select Functional and Structural Components Area	
Paradigm	Opens the Paradigm selection menu, displaying a list of the processed paradigms available for display. This list includes a special item, Composite Z-Map, that can be used to display all the paradigms listed simultaneously with separate colors assigned to the paradigm results and overlapping areas. Refer to the BrainWave Paradigms section of this chapter for a complete list of paradigms and their descriptions.
Overlay Type	Opens the Overlay Type selection menu, allowing you to select the type of image on which to impose the color ramps. The overlay types include Segmented sMRI*, Nonsegmented sMRI*, and Mean fMRI Image Volume.
Thresholding Area	
$p < 0.05$	The default thresholding factor. Selecting this factor means you have a 95% confidence level the activation recorded was not noise, based on the calculation used by the AW BrainWave application.
Relative	Enables the thresholding slider, which you can use to manually set the thresholding factor. Sliding the bar to the left to evaluates fewer activations, thus increasing the confidence level. Sliding the bar to the right to evaluates more activations, thus decreasing the confidence level.
[Create/Update Functional - Structural Overlay]	Fuses the functional activation map and the segmented structural scan to overlie one another. The fused data is then displayed in the Volume Rendering Viewer.
[Display Text Report]	Displays the text report for structural overlaid data.

NOTE: *Structural Magnetic Resonance Imaging (sMRI)

Overlay Types

Once the functional data has been acquired and processed, specific paradigm information can be overlaid on selected image types.

- Segmented - sMRI
- Nonsegmented - sMRI
- Mean fMRI Image Volume

A segmented image is an image with the skin and skull extracted from the 3D volume image. A nonsegmented image is an image in which the entire volume is displayed just as it was acquired, with all the surrounding brain tissues seen. Mean fMRI images are images from the EPI data set.

Once the functional/structural overlay has been created, images are displayed fused with parametric data in the BrainWave Visualizer. Images can either be displayed using the Volume Rendering View or the Lightbox View. The Volume Rendering View is the default viewer for structural overlay.

NOTE: Refer to the Visualize fMRI Data chapter for additional viewer information and concepts.

Display Text Report

The Text Report is a description of the image processing performed for your selected patient. This report includes parameters specific to the particular study, e.g., the completed adjusted threshold used for image fusion. This type of report aids in making a formal radiologic dictation/report for the brain mapping study. This information can also be used for scientific writings for publication. A copy of this report is transferred along with the fMRI study to the AW. It is stored in the Image Comments Digital Imaging and COmmunication in Medicine (DICOM) area.

NOTE: A Text Report can not be printed, nor does it contain an interpretation of the results.

BrainWave Messages

During the visualize phase, the BrainWave Message area displays a color legend. The color legend shows how to interpret the colors in an image display. The interpretation of color is especially important in the overlays of the Mean EPI image volume with the structural MRI data. Figure 8-13 shows an example of an Average EPI Color Legend.

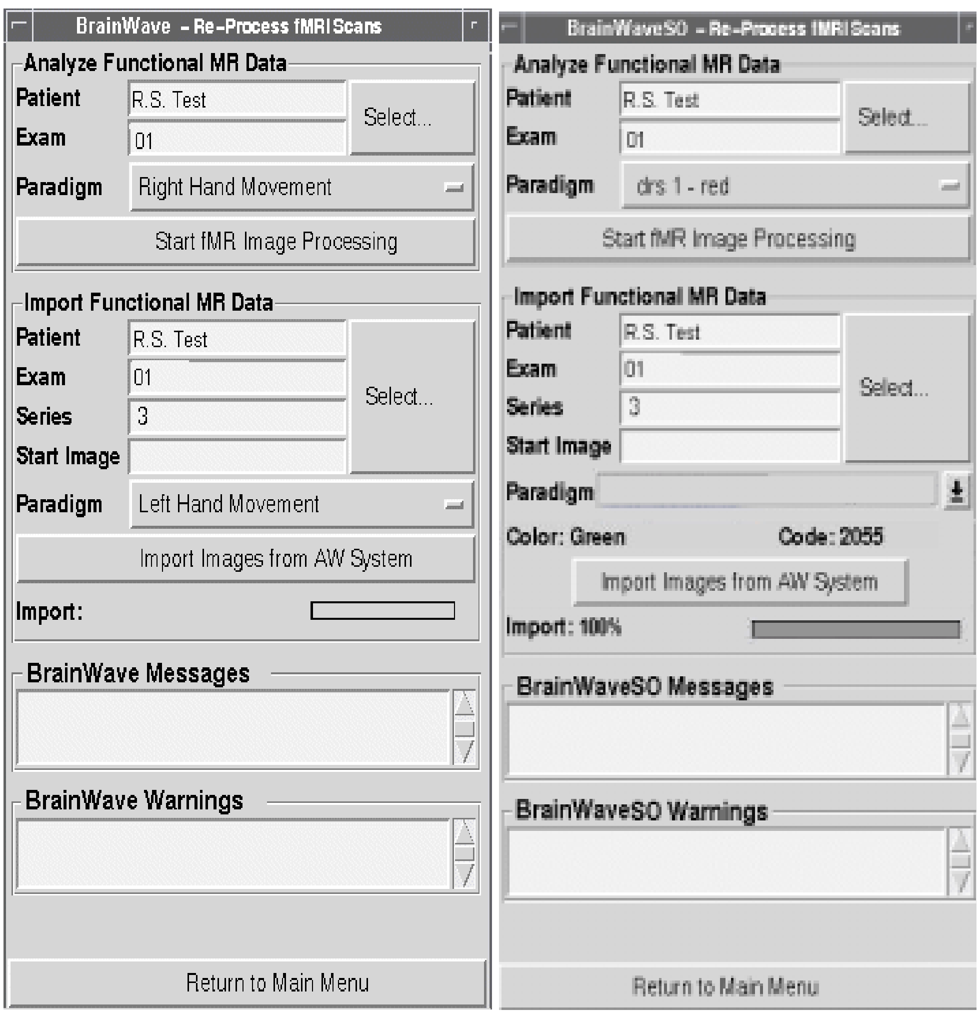
Figure 8-13 Average EPI Color Legend Example

Color Legend:
Green: fMRI and sMRI data overlap
Red: sMRI data present but no fMRI data
Blue: fMRI data present but no sMRI data

Re-Process fMRI Scans Window

The Re-Process fMRI Scans window (Figure 8-14) is accessed with the **[Re-Process fMRI Scans]** button on the Main Menu. This window is broken up into two main areas: Analyze Functional MR Data, and Import Functional MR Data.

Figure 8-14 BrainWave Re-Process Window (left) and BrainWaveSO Re-Process Window (right)



Re-processing fMRI scans may be required if your fMRI process has been manually aborted or if the system malfunctions. Through this window, you can reimport functional MR data from your AW and start the fMRI image processing. Table 8-6 provides a description of each selection in this window.

Table 8-6 Re-Process fMRI Display Selections

Selection	Description
Analyze Functional MR Data Area	
Patient	Displays the patient ID number.
Exam	Displays the patient exam number.
Paradigm	Displays the list of paradigms performed on this patient. Refer to the BrainWave Paradigms section of this chapter for additional information.
[Start fMR Image Processing]	Begins the fMRI image processing if the image processing has been aborted.
Import Functional MR Data Area	
Patient	Displays the list of patients on the AW workstation.
Exam	Allows selection of the patient exam on which you wish to import the functional data.
Series	Displays the patient series on which you wish to import the functional data.
Start Image	Displays the image number you wish the system to start importing.
Paradigm	Allows selection of the fMRI paradigm that corresponds to the selected series. This requires you know which series maps to which paradigm.
[Import Images from AW System]	Transfers the selected exam, series, and images you requested.
Paradigm color	**Only with BrainWaveSO** Represents activation areas associated with the paradigm when a Composite Z-Map display is created. The Z-Map color and code for the selected paradigm is displayed above the **[Import Images from AW System]** button. Use this information to cross-reference with the selected paradigm.
Import	Provides a quick view of the image transfer completion status.

Manage System Window

The Manage System tool of the BrainWave software can be accessed from the Main Menu via the **[Manage System]** button. The Manage System window (Figure 8-15) includes the following functions:

- Deletion of Stimulus PC log files (only with BrainWave)
- Management of the stimulus delivery system (only with BrainWave)
- Modification of configuration defaults

Figure 8-15 BrainWave Manage System Window (left) and BrainWaveSO Manage System Window (right)

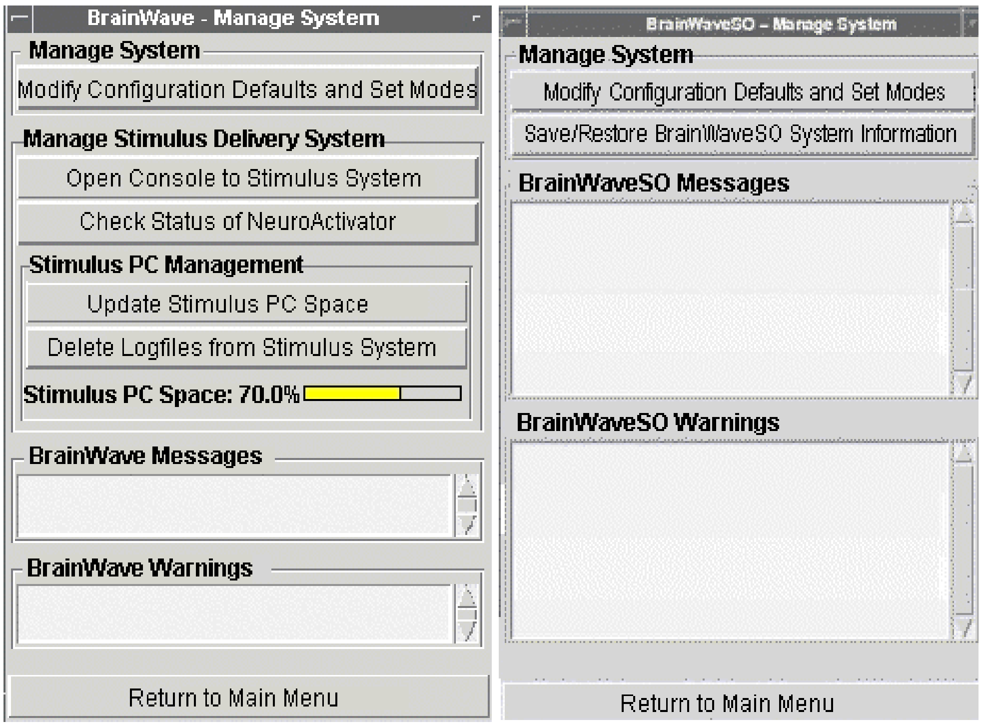


Table 8-7 provides a description of the Manage System window selections.

Table 8-7 Manage System Window Selections

Selection	Description
Manage System Area	
[Modify Configuration Defaults and Set Modes]	Allows you to specify the flatfile, BrainWave data directories, and network parameters. Any modifications to this area should only be performed by a service engineer.
Save/Restore BrainWaveSO System Information	**Only with BrainWaveSO** Allows saving files you built in the acquisition program to a floppy disk. It is important to save your paradigm files so in the event you need to restore the files, they match your previous paradigm names. The paradigm name is used as the description in the AW Browser, in the paradigm pull-down menu on the Acquire fMRI Scans window, and as image annotation.

Selection	Description (Continued)
Manage Stimulus Delivery System Area: Only with BrainWave	
[Open Console to Stimulus System] or **[Close Console to Stimulus System]**	Opens or closes the stimulus presentation software on the AW. The **[Close Console to Stimulus System]** is only seen when the **[Open Console to Stimulus System]** has been selected.
[Check Status of NeuroActivator]	Performs a status inquiry of the stimulus delivery system and displays messages in the Message area.
Stimulus PC Management: Only with BrainWave	
[Update Stimulus PC Space]	Updates the Stimulus PC Space status meter.
[Delete Logfiles from Stimulus System]	Removes patient response data from the PC.
Stimulus PC Space	Displays the percentage of total space in the log directory being used via a status meter.

Image Databases

When performing an fMRI exam, you need to be concerned with four main databases (Figure 8-16).

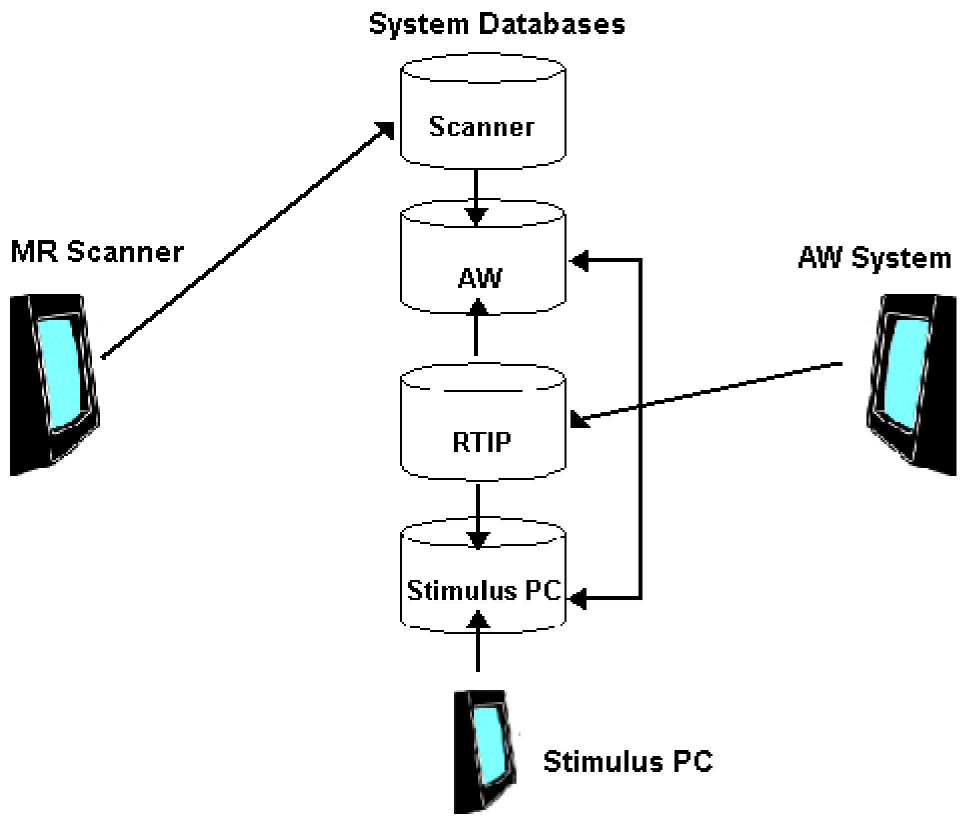
- MR System Database - contains all data files created by the system
- AW Database - contains all data files created by various software packages pre-loaded or transferred to the system
- Real Time Image Processing (RTIP) Database - contains image data files created only by the RTIP software
- Stimulus PC Database - contains the logfiles of patient responses

With an fMRI exam, the databases constantly interact with one another. Upon acquiring your 3D SPGR data set, images are stored in your MR system database. Images are then transferred from this database to the AW database. From here, these images can be used by the BrainWave software for image segmentation.

Once you have started the functional task portion of the exam, images are actively stored both in the AW database and the RTIP database. The logfiles of patient responses are stored on the Stimulus PC. When you are ready to display your images, the BrainWave software requires you to select the patient series from the AW database.

NOTE: Periodically, all databases need to be cleared to allow space for additional functional studies. Refer to your RTIP and AW documentation for the correct deletion procedures.

Figure 8-16 Internal Database Diagram



How Do I...

This section provides the step-by-step instructions for obtaining images visualizing white matter tracts. Specifically, it describes how to:

- Set Up the Visual Equipment (BrainWave only)
- Perform an fMRI Exam
  - Set Up the Patient (BrainWave only)
  - Set Up the Patient (BrainWaveSO only)
  - Prescribe and Perform the Localizer and 3D SPGR Series
  - Perform 3D Segmentation
  - Acquire the fMRI Data
  - Visualize the fMRI Data
- Reprocess fMRI Data
- Import fMRI Data
- Save/Restore BrainWaveSO System Information
- Print Color Images
- Delete Logfiles
  - Remove all Logfiles (BrainWave only)
  - Remove Selected Logfiles

Set Up the Visual Equipment (BrainWave only)

Quick Steps: Set Up the Visual Equipment (BrainWave only)

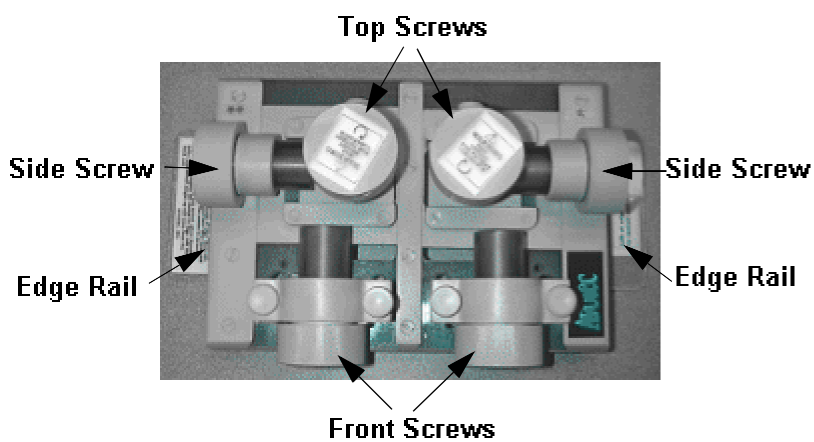
1. Place the glasses mount on the head coil bars.
2. Hold the edge rails between your thumbs and pointer finger.
3. Slightly lift the edge rails while pressing the glasses mount downward.
4. Release the edge rails.
5. Verify the mount is securely attached to the head coil.
6. Insert the top of the glasses into the bottom of the glasses mount.
7. Tighten the top screws on the glasses mount.
8. Screw the Track to the Holder Clamp.

NOTE: If your system operates BrainWaveSO, follow the manufacturer's equipment setup guidelines.

Visual equipment allows your patient to view stimuli being presented, without head movement. The stimulus can be in the form of words or geometric shapes.

Use this procedure to set up the visual equipment by attaching the high resolution glasses to the head coil. This procedure should be done prior to an exam involving visual paradigms.

1. Place the glasses mount on the head coil bars.



Glasses Mount

- The front screws should be facing the front of the head coil.

2. Hold the edge rails between your thumbs and pointer finger.

- This ensures a firm grip on the glasses mount.

Attaching Glasses Mount

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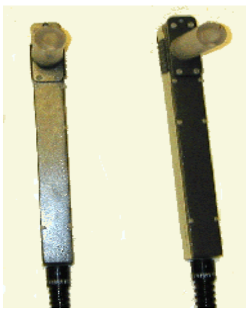
3. Slightly lift the edge rails while pressing the glasses mount downward.
   - This spreads the clamps, located on the bottom of glasses mount, apart.
4. Release the edge rails.
   - This closes clamps around head coil bars.
5. Verify the mount is securely attached to the head coil.
   - The glasses mount should not move around on head coil when it is touched.
   - If the glasses mount is not secure, repeat steps three through six.

NOTE: The glasses mount should always be securely fastened to the head coil to prevent patient injury.

6. Insert the top of the glasses into the bottom of the glasses mount.
   - The cables of the glasses should exit out the back of the head coil.
   - The glasses can be inserted into either mount.



Top View

Glasses

7. Tighten the top screws on the glasses mount.
   - This secures glasses to the glasses mount.
8. Screw the Track to the Holder Clamp.
   - This secures the Track to the Holder Clamp.

Perform an fMRI Exam

Set Up the Patient (BrainWave only)

Quick Steps: Set Up the Patient (BrainWave only)

1. Provide the patient with the Patient Alarm and explain the procedure to your patient.
2. Place protective headset covers on the earphones.
3. Place the earphones on your patient, if applicable to the paradigm, or provide earplugs.
4. Adjust the earphones or earplugs to ensure patient comfort.
5. Position your patient's head in the head coil cradle.
6. Slowly slide the head coil over the patient's head.
7. Adjust the glasses, if necessary.
8. Give your patient the hand controls.
9. Landmark your patient for a brain exam.
10. Press **Advance to Scan**.
11. Press the microphone control to the **ON** position.
12. Adjust the microphone, if necessary.
13. Choose the appropriate audio control.
14. Adjust your patient's voice control, if necessary.

Patient preparation is a very important part of an fMRI exam. To effectively perform the exam, your patient needs to know what is happening during the procedure and what actions are required.

Use this procedure to set up the patient with the sensory equipment. If you are performing an exam using a visual paradigm, make sure you perform the steps in the visual equipment setup prior to this portion of the exam.

1. Provide the patient with the Patient Alarm and explain the procedure to your patient.
   - Refer to the Patient Preparation sections of each paradigm for suggested instructional dialogs for each paradigm.
   - Tell the patient to activate the alarm any time during the test if he or she is unable to hear instructions through the head phones.
2. Place protective headset covers on the earphones.
   - The protective headset covers keep the earphones clean from one patient to the next.

Headset Covers

3. Place the earphones on your patient, if applicable to the paradigm, or provide earplugs.
   - The microphone should be facing up, towards the patient's mouth. The earphones allow delivery of the stimulus and protect hearing from gradient noise.

Earphones

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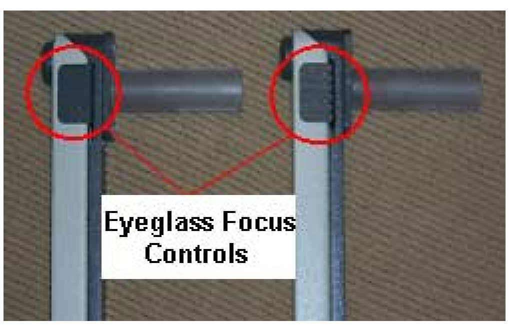
4. Adjust the earphones or earplugs to ensure patient comfort.
   - Expand and contract the earphones, as needed, to ensure they are comfortable for your patient.
5. Position your patient's head in the head coil cradle.
   - Make sure your patient is comfortable.
6. Slowly slide the head coil over the patient's head.
   - Make sure there is enough clearance between the patient's head and the glasses, if the glasses are being used.

fMRI Patient in Head Coil with Glasses

7. Adjust the glasses, if necessary.
   a) Adjust the side controls to move the glasses from right to left.
   b) Adjust the front controls to move the glasses up and down to ensure your patient can clearly see the image.
   c) Have the patient adjust the focus by moving the focus slider controls.



Eyeglass Controls

8. Give your patient the hand controls.

- The correct hand positioning is important for a successful examination.
  - Left hand: blue/yellow control buttons
  - Right hand: red/green control buttons

9. Landmark your patient for a brain exam.
   - The nasion is the proper brain landmark for brain studies.

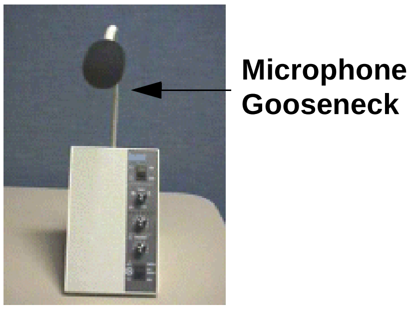
10. Press **Advance to Scan**.
    - This moves your patient to the landmarked position in the magnet bore.

11. Press the microphone control to the **ON** position.

Microphone On/Off Switch

12. Adjust the microphone, if necessary.

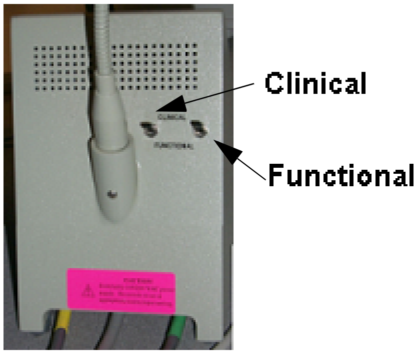
a) Adjust the gooseneck of the microphone, to where it is in a comfortable position for communicating with your patient.



Microphone Control

b) Adjust the sound volume to a level comfortable for the patient to hear the audio stimulus.

c) If the paradigm requires an audio stimulus, set the microphone to Clinical mode. This is done from the back of the microphone by setting the two switches to Clinical. Although the audio operates when the switches are set to Functional mode, it may not be clearly heard or understood by the patient. Clinical mode provides a larger range of volume.



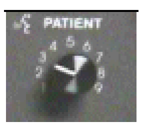
Backside of Microphone

NOTE: Media controls are not operational with the fMRI option. Paradigms are delivered to your patient via brain mapping software.

13. Choose the appropriate audio control.

- Select the **Music** position when no instructions are being given to your patient
- Select the **No Music** position when listening to your patient and no instructions are being given to the patient.
- Select the **Mic** position when speaking to your patient.
  – Typically place your mouth 2 inches away from the microphone and speak directly into it. Do not speak off to the side of the microphone.
  – The volume for the microphone is set by the factory and can not be adjusted using the music volume control.

14. Adjust your patient's voice control, if necessary.



- This ensures the level at which you hear your patient is adequate.

NOTE: The patient's microphone is always active, even while the music or instructions are being delivered.

Quick Steps: Set Up the Patient (BrainWaveSO only)
1. Follow the manufacturer's guidelines for setting up the patient.
2. Landmark your patient for a brain exam.
3. Press **Advance to Scan**.

Set Up the Patient (BrainWaveSO only)

Patient preparation is a very important part of an fMRI exam. To effectively perform the exam, your patient needs to know what is happening during the procedure and what actions are required.

Use this procedure to set up the patient if your system is operating BrainWaveSO software.

1. Follow the manufacturer's guidelines for setting up the patient.
2. Landmark your patient for a brain exam.
   - The nasion is the proper brain landmark for brain studies.
3. Press **Advance to Scan**.
   - This moves your patient to the landmarked position in the magnet bore.

Perform an fMRI Exam

Prescribe and Perform the Localizer and 3D SPGR Series

There are two series that must be performed prior to acquiring the fMRI acquisition: the localizer and the 3D volume sequence of the whole brain. The 3D sequence is later used to overlay the task activation color maps.

The structural exam may be acquired before or after the task activation series. Acquiring the task activation part of the exam at the beginning can often ensure the patient is more alert than at the end of the exam. If acquiring the structural series at the end of the exam, you must send the localizer scan to the AW before starting the task activation.

Use this procedure to set up and scan the localizer series for the fMRI exam. Your patient should be set up for an fMRI exam prior to beginning these steps.

1. Enter the patient information.
2. Prescribe a 3-Plane Localizer series of the head.
   - Make sure the Scanning Range parameters are large enough to cover the entire brain.
3. Click **[Save Series]**.
   - This saves the localizer series.
4. Click **[Prepare to Scan]**.
   - This downloads the localizer series.
5. Click **[Scan]**.
   - This performs the Auto Prescan and initiates the localizer acquisition.
6. Click **[New Series]**.
   - This adds an additional series to the patient's exam.

Quick Steps: Prescribe and Perform the Localizer and 3D SPGR Series

1. Enter the patient information.
2. Prescribe a 3-Plane Localizer series of the head.
3. Click **[Save Series]**.
4. Click **[Prepare to Scan]**.
5. Click **[Scan]**.
6. Click **[New Series]**.
7. Prescribe a 3D SPGR sequence.
8. Click **[Save Series]**.
9. Click **[Prepare to Scan]**.
10. Click **[Scan]** to initiate Auto Prescan and start the 3D SPGR acquisition.

7. Prescribe a 3D SPGR sequence.

Parameter Selection	What You Select
Imaging Parameters	
Patient Position	Supine
Patient Entry	Head First
Coil	Head
Plane	Axial
Mode	3D
Pulse Sequence	SPGR
Grad Mode	Zoom
Imaging Options	Variable Bandwidth
Scan Timing	
# of Echoes	N/S
TE	Min Full
TR	30
Flip Angle	45
Bandwidth	15.63
Scanning Range	
FOV	24 cm
Slice Thickness	1.2 mm
Spacing	0
Start Location	Graphic Rx
End Location	Graphic Rx
# of Slices	124

Parameter Selection	What You Select
Acquisition Timing	
Freq	256
Phase	192
NEX	1
Phase FOV	0.75
Freq DIR	A/P
Auto Center Freq	Water
Flow Comp DIR	N/A
Autoshim	On
Phase Correct	N/A
# of Locs Before Pause	N/A
Additional Parameters	
SAT	None
Graphic Rx	Cover the entire brain.

- This is a protocol example.
- The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.

8. Click **[Save Series]**.
9. Click **[Prepare to Scan]**.
   - This downloads the 3D SPGR series.
10. Click **[Scan]** to initiate Auto Prescan and start the 3D SPGR acquisition.

Perform an fMRI Exam

Perform 3D Segmentation

Segmentation is the process of extracting the bone and skin from a 3D volume image. The resulting image is a 3D model of the brain, which can be later used to overlay task activation color maps.

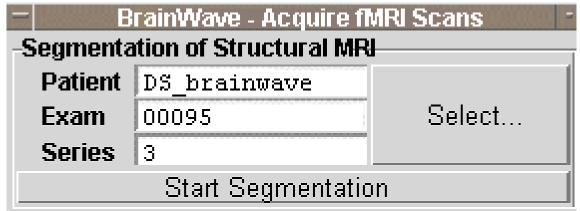
Use this procedure to perform the segmentation of your 3D SPGR image. Your patient should be set up and the localizer series should be acquired prior to beginning these steps.

1. Click the **Management Desktop** icon.
   - This opens the Network Browser.
2. Select **Network > Select Remote Host**.
3. Select AW as the host.
   - This is the host to which you want to transfer your images.
4. Click **[OK]** to register the network selections.
5. Select the 3D SPGR series.
   - This prepares the series to be transferred.
6. Select **Network > Send Series**.
   - This displays the confirmation window.
7. Click **[OK]** to transfer the images to the AW.
8. Select **More Software > BrainWave** or **BrainWaveSO**.
   - This launches the BrainWave software.
9. Select **Acquire fMRI Scans** from the BrainWave Main Menu.
   - This opens the fMRI Scans window.

Quick Steps: Perform 3D Segmentation

1. Click the **Management Desktop** icon.
2. Select **Network > Select Remote Host**.
3. Select AW as the host.
4. Click **[OK]** to register the network selections.
5. Select the 3D SPGR series.
6. Select **Network > Send Series**.
7. Click **[OK]** to transfer the images to the AW.
8. Select **More Software > BrainWave**.
9. Select **Acquire fMRI Scans** from the BrainWave Main Menu.
10. Click **[Select]**.
11. Select the correct patient and 3D SPGR series from the Browser.
12. Click **[Import and start segmentation automatically]**.

10. Click **[Select]**.

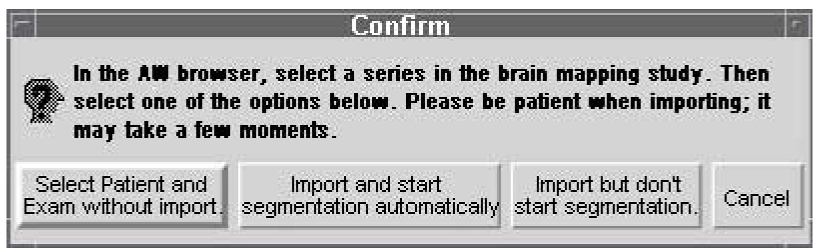


Acquire fMRI Scans Window

- A confirmation message window and the Browser open.

11. Select the correct patient and 3D SPGR series from the Browser.
    - If your patient is not listed, try re-networking your patient's 3D SPGR sequence from the scanner console.

12. Click **[Import and start segmentation automatically]**.



Confirmation Message Window

- If you are acquiring the task activation before the structural exam, click **[Select Patient and Exam without import]**.
- This registers your patient's information into the appropriate text boxes in the Segmentation of Structural MRI area and begins the segmentation process.
  - The Processing Status window opens and indicates processing is occurring. Watch the status bar until it is filled, and watch the messages that appear to the right of the status bar. Processing may take a while.
  - As segmentation is taking place, your fMRI data acquisition can be started. Refer to the next section for this procedure.
- The **[Import but don't start segmentation]** button is used in cases where only structural scanning is desired.

NOTE: If any segmentation imperfections should occur, these should not be interpreted to indicate underlying pathology.

Perform an fMRI Exam

Acquire the fMRI Data

Before you can visualize any functional data, you must first acquire it. Acquiring fMRI data involves the actual scanning of the task areas of the brain.

Use this procedure to acquire your fMRI data. Your patient should be set up, a localizer series should be acquired, and 3D Segmentation should be performed prior to starting these steps.

NOTE: The segmenting process takes a while, therefore it is recommended you start the process prior to beginning these steps.

1. Click **[New Series]**.
   - This adds an additional series to the patient's exam.
2. Prescribe the fMRI sequence.

Parameter Selection	What You Select
Imaging Parameters	
Patient Position	Supine
Patient Entry	Head First
Coil	Head
Plane	Axial
Mode	2D
Pulse Sequence	Gradient Echo EPI
Grad Mode	Zoom
PSD Name	epi_gre_64
Scan Timing	
# of Shots	1
TE	40
TR	4000
Flip Angle	90
Echo Train Length	N/A
Bandwidth	62.5

Parameter Selection	What You Select
Acquisition Timing	
Freq	64
Phase	64
NEX	1
Phase FOV	1
Freq DIR	R/L
Auto Center Freq	Water
Flow Comp DIR	N/A
Autoshim	On
Phase Correct	On
Additional Parameters	
SAT	None
Graphic Rx	Cover the entire brain.

Quick Steps: Acquire the fMRI Data

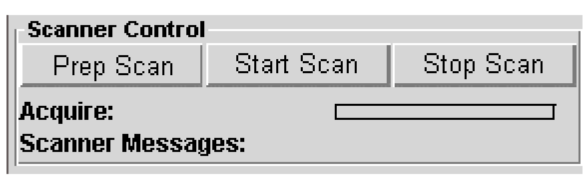
1. Click **[New Series]**.
2. Prescribe the fMRI sequence.
3. Save and download the fMRI series.
4. Press **Move to Scan**, if necessary.
5. Select the desired paradigm from the Paradigm list on the AW.
6. Click **[Prep Scan]** on the AW.
7. Click **[New Template]**.
8. Tell your patient the tasking sequence is about to begin.
9. Click **[Start]** on the BrainWave Acquisition panel.
10. Click **[Open Console to Stimulus System]** in the Acquire fMRI Scans window.
11. Click **[Close Console to Stimulus System]**.
12. After the current Stimulus series is completed, print the plot graphs, if desired.
13. Repeat step 6, and 9 -13 to acquire an additional paradigm sequence.
14. When the scan is complete, click **[Return to Main Menu]**.

Parameter Selection	What You Select
Scanning Range	
FOV	24 cm
Slice Thickness	3 mm
Spacing	0
Start Location	Graphic Rx
End Location	Graphic Rx
# of Slices	40

Parameter Selection	What You Select
User CVs	
Ramp Sampling	0
PSD Trigger	0
# of RTC Dummy Acqs	4
Initial State	0
Baseline Duration	6
Stimulation Duration	6
Scan Duration	96
Delay after each slice package	1

NOTE: The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.

3. Save and download the fMRI series.
   a) Click **[Save Series]**.
   b) Click **[Prepare to Scan]**.
      – This downloads the fMRI series.
4. Press **Move to Scan**, if necessary.
   - Located on your MR system keyboard.
   - Advances the table to the correct starting location.
5. Select the desired paradigm from the Paradigm list on the AW.
   - Refer to the BrainWave Paradigms section of this chapter for a description of each paradigm.
6. Click **[Prep Scan]** on the AW.



Scanner Control Area of Acquire fMRI Scans Window

   - This step must be performed on the AW, not your scanner console.
   - Opens the RealTime Imaging window.

7. Click **[New Template]**.
   - This only occurs with the first paradigm after the first Prep Scan.
   - Creates a template image used for image header information once the fMRI series is started.
   - Performs Auto Prescan and the EPI reference scan.
   - Creating a new template is only required on the first paradigm sequence.
8. Tell your patient the tasking sequence is about to begin.
   - Ensures your microphone is working correctly and your patient is ready for the tasks.
9. Click **[Start]** on the BrainWave Acquisition panel.
   - It is important NOT to use the **[Start]** button on the Real Time panel as this results in the BrainWave application getting out of synchronization with realtime scanning.
   - This step must be performed on your AW, not your scanner console.

NOTE: BrainWaveSO does not include stimulus hardware, therefore, skip to step 13. You are responsible for keeping stimulus presentation in synchronization with scanning when using BrainWaveSO.

10. Click **[Open Console to Stimulus System]** in the Acquire fMRI Scans window.
    - Opens the Stimulus PC window, displaying the Patient Responses and Motion Detection windows.
    - Make sure the screen advances past the introduction paradigm screen and flashes Ready. This ensures the patient is seeing and/or hearing the stimulus. If you don’t see the “Ready” message flash, then quit the scan and call service.
11. Click **[Close Console to Stimulus System]**.
    - Closing this window reduces the network traffic and helps to ensure a successful scan.

12. After the current Stimulus series is completed, print the plot graphs, if desired.
    a) Click **[Print Plot]** in the Patient Responses window.
    b) Click **[Print Plot]** in the Motion Detection window.
       – Paper copies of the patient's graphs can only be printed if you have a color printer.
       – The graphs must be printed prior to starting another paradigm.
13. Repeat step 6, and 9 - 13 to acquire an additional paradigm sequence.
    - The following substeps are only necessary if you are performing an additional paradigm sequence.
14. When the scan is complete, click **[Return to Main Menu]**.
    - Prepares you for visualizing your patient's data.

WARNING: **Do not prescribe additional fMRI sequences while acquiring a fMRI sequence. This may cause system problems.**

Perform an fMRI Exam

Visualize the fMRI Data

Visualizing the fMRI data involves the creation of structural overlays of the color maps. These steps can only be performed after the data has been acquired.

NOTE: If the Browser is open, please close it before starting this procedure.

1. Click **[Visualize Maps]**.
   - Launches the BrainWave visualization tool.
   - Automatically completes patient data information.
   - If the displayed patient name or exam number is not the patient you currently want to visualize, click **[Select]**, double-click the Patient Name, click the exam number, and click **[Select]**.
2. Click **[Import from AW Browser]**, if necessary.
   - Only perform this step if the patient name is not the patient you want to visualize data on.

   a) Select your patient's name.

   b) Click **[OK]**.
3. Select the desired paradigm information you want to visualize from the Paradigm list.
   - The Paradigm list only displays the paradigms you have acquired on this patient.
   - Refer to the BrainWave Paradigms section of this chapter for a description of each paradigm.
4. Select the desired type of overlay from the Overlay Type predefined list.
   - The Overlay Type list displays the image sets upon which functional maps can be overlaid.
   - Refer to the Visualize Maps Window section of this chapter for a brief description of each overlay type.
5. Select the thresholding factor.
   - The recommended and defaulted factor is $p<0.05$. Selecting this means data is demonstrating 95%

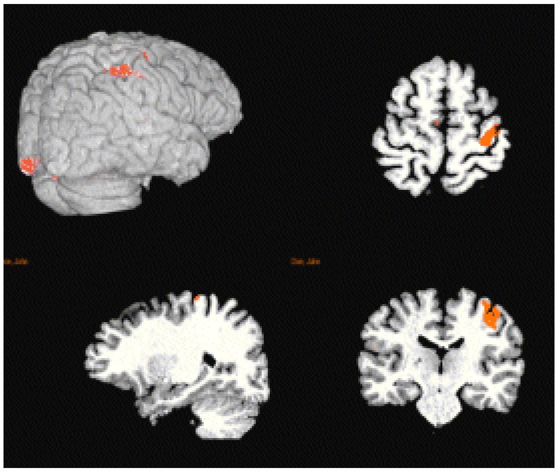
Quick Steps: Visualize the fMRI Data

1. Click **[Visualize Maps]**.
2. Click **[Import from AW Browser]**, if necessary.
3. Select the desired paradigm information you want to visualize from the Paradigm list.
4. Select the desired type of overlay from the Overlay Type predefined list.
5. Select the thresholding factor.
6. Click **[Create/Update Functional - Structural Overlay]**.

confidence that there is statistical significance between the control and activation states.

- Select Relative if you wish to adjust the threshold manually.
  - Move the Relative slider from left to right to adjust to the threshold setting.

6. Click **[Create/Update Functional - Structural Overlay]**.
   - Overlays functional activation map on the segmented structural data.



Example of a Structural Overlay

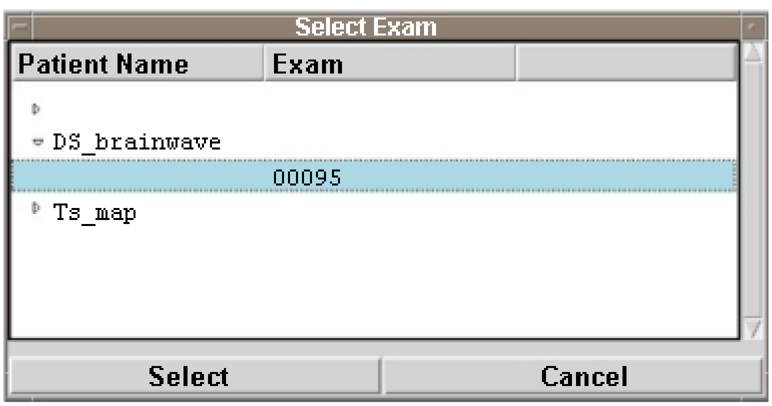
NOTE: Refer to the Visualize fMRI Data chapter for viewing options and functions.

Reprocess fMRI Data

Once the acquisition of the fMRI scan is complete, your system automatically starts analyzing and processing the fMRI data. However, there may be times when you need to restart the analysis and processing of this data. For example, if the analysis and processing had been manually aborted, you need to process the data prior to viewing or manipulating the fMRI images.

Use this procedure to start the analysis application and process your fMRI data. This procedure can only be performed after the fMRI scan is complete.

1. Click **[Re-Process fMRI Scans]**.
   - Located on the BrainWave Main Menu.
   - Launches the BrainWave processing tool.
2. Click **[Select]**.
   - Located in the Analyze Functional MR Data area of the Re-Process window.
   - Opens the Select Exam window.



Select Exam Window

3. Double-click the name of the patient you want to analyze.
   - Highlights the patient name you selected.
   - Displays the list of exams performed on the selected patient.
4. Click the exam number which corresponds to the fMRI data set you want to analyze.
   - Highlights the exam you selected.

Quick Steps: Reprocess fMRI Data

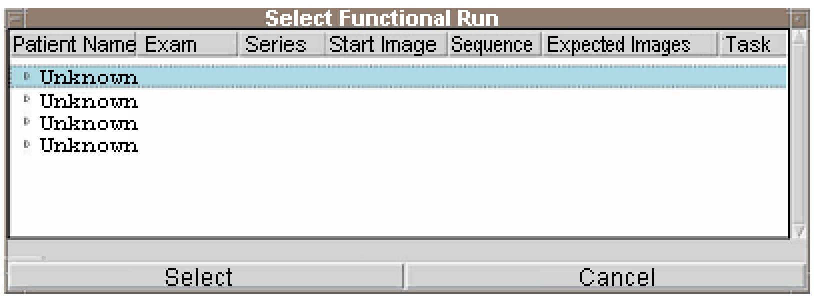
1. Click **[Re-Process fMRI Scans]**.
2. Click **[Select]**.
3. Double-click the name of the patient you want to analyze.
4. Click the exam number which corresponds to the fMRI data set you want to analyze.
5. Click **[Select]**.
6. Select the desired paradigm information you want to visualize from the Paradigm list.
7. Click **[Start fMR Image Processing]**.
8. Click **[Abort fMRI Image Processing]**, if necessary, to stop the analysis process.

5. Click **[Select]**.
   - Closes the Select Exam window and automatically fills in the **Patient** and **Exam** text boxes with the patient you selected.
6. Select the desired paradigm information you want to visualize from the Paradigm list.
   - The Paradigm list only displays the paradigms you have acquired on this patient.
   - Refer to the BrainWave Paradigms section of this chapter for a description of each paradigm.
7. Click **[Start fMR Image Processing]**.
   - Initiates the analyze process of the fMRI data.
   - Opens the Processing Status window.
   - This button label changes to **[Abort fMRI Image Processing]** option once the process begins.
8. Click **[Abort fMRI Image Processing]**, if necessary, to stop the analysis process.

Import fMRI Data

Use this procedure to import fMRI data from the AW if the acquired data does not appear in the BrainWave Browser.

1. Click **[Re-Process fMRI Scans]**.
   - Located on the BrainWave Main Menu.
   - Launches the BrainWave processing tool.
2. Click **[Select]**.
   - Located in the Import Functional MR Data area of the Re-Process fMRI Scans window.
   - Opens the Select Functional Run window.



Select Functional Run Window

3. Double-click the name of the patient you want to import.
   - Highlights the patient name you selected.
   - Displays the list of exams performed on the selected patient.
4. Double-click the exam number corresponding to the fMRI data set you want to import.
   - Highlights the exam you selected.
   - Displays the lists of series performed on the selected patient.
5. Click the series number corresponding to the fMRI data set you want to import.
   - Highlights the series you selected.
6. Click **[Select]**.
   - Closes the Select Exam window and automatically fills in the **Patient** and **Exam** text boxes with the patient you selected.

Quick Steps: Import fMRI Data

1. Click **[Re-Process fMRI Scans]**.
2. Click **[Select]**.
3. Double-click the name of the patient you want to import.
4. Double-click the exam number corresponding to the fMRI data set you want to import.
5. Click the series number corresponding to the fMRI data set you want to import.
6. Click **[Select]**.
7. Select the desired paradigm you wish to analyze from the Paradigm list.
8. Click **[Import Images from the AW System]**.

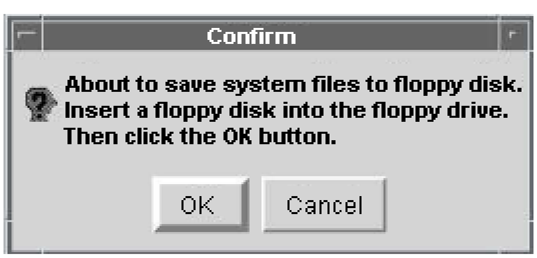
7. Select the desired paradigm you wish to analyze from the Paradigm list.
   - The Paradigm list only displays the paradigms you have acquired on this patient.
   - Refer to the BrainWave Paradigms section of this chapter for a description of each paradigm.
8. Click **[Import Images from the AW System]**.
   - Transfers the selected series of the patient to the BrainWave database.
   - This continues with analysis.

Save/Restore BrainWaveSO System Information

Use this procedure to save or restore your paradigm name and code table. Save your tables every time you change the paradigm table so if you have a software upgrade or you need to recover from a disk crash, you will be able to restore the most recent paradigm table.

1. Click **[Manage]** in the Main menu.
2. Click **[Save/Restore BrainWaveSO System Information]**.
3. Type-in your password and click **[OK]**.
   - This is the same password that is used by the administrator when modifying the configuration defaults and setting the modes.
   - Only the administrator who manages the paradigm table should be saving and restoring paradigms.
4. Put the floppy in the drive to which you are either saving or restoring paradigm tables.
5. Click a save or restore option.

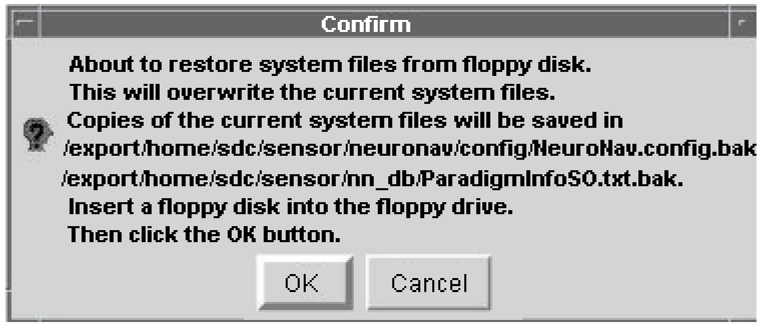
   - **[Save Information to Floppy Disk]** saves the paradigm table to floppy disk, **[Restore Information from Floppy Disk]** restores the paradigm table from floppy disk to the system disk.
6. Click **[OK]** to confirm your selection.



Save Information to Floppy Disk Confirmation Prompt

Quick Steps: Save/Restore BrainWaveSO System Information

1. Click **[Manage]** in the Main menu.
2. Click **[Save/Restore BrainWaveSO System Information]**.
3. Type-in your password and click **[OK]**.
4. Put the floppy in the drive to which you are either saving or restoring paradigm tables.
5. Click a save or restore option.
6. Click **[OK]** to confirm your selection.



Restore Data to Hard Drive Confirmation Prompt

Print Color Images

Brain Mapping images are parametric color maps overlying EPI or 3D volume images. These images are helpful in visualizing areas of task activation and intensity levels of the activated areas. Printing the images provides a permanent hard copy of task activated areas in the brain.

In order to print color images, you must have a color printer connected to your system. A service engineer could assist you with the connection of such a printer.

1. Click the image you wish to print.
    - You can do this from the Lightbox View or Volume Rendering viewers.
    - Highlights the viewport of the image you wish to print.
2. Select **File > Print**.
    - Located across the top portion of the viewer.
3. Repeat steps one and two, for any additional views you wish to print.

NOTE: Images can also be printed from the AW. Refer to your AW documentation for printing instructions. *Images printed from your AW can not be printed in color.*

Quick Steps: Print Color Images

1. Click the image you wish to print.
2. Select **File > Print**.
3. Repeat steps one and two, for any additional views you wish to print.

Quick Steps: Remove all Logfiles (BrainWave only)

1. Click **[Manage System]**.
2. Click **[Delete Logfiles from Stimulus System]**.

Delete Logfiles

Remove all Logfiles (BrainWave only)

When performing an fMRI exam, patient responses to the paradigm stimuli are recorded and stored on your Stimulus PC. These logfiles eventually need to be deleted to provide space for future acquisition logs.

Use this procedure to remove all the logfiles from the Stimulus PC. These steps should only be performed after the fMRI exam is complete and brain mapping has been performed.

1. Click **[Manage System]**.
   - This is located on the Main Menu of the BrainWave window.
2. Click **[Delete Logfiles from Stimulus System]**.
   - This removes all logfiles from the Stimulus system.

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Delete Logfiles

Remove Selected Logfiles

Use this procedure to only remove selected logfiles from the Stimulus PC. These steps should only be performed by an advanced Stimulus PC user, after the fMRI exam is complete.

1. Click **[Manage System]**.
    - This is located on the Main Menu of the BrainWave window.
2. Click **[Open Console to Stimulus System]**.
    - This opens the Stimulus PC window.
3. Position your cursor in the console window.
    - Temporarily stops the “four boxes” display for approximately five seconds.

NOTE: Your cursor must remain in the console window for the remainder of the steps. This ensures proper procedure functioning.

4. Right-click on the **NeuroActivator** icon.
    - This is located on the right bottom side of the Windows task bar.
    - This opens the NeuroActivator window.
5. Click **[Exit]**.
    - This stops the NeuroActivator application so the “four boxes” display does not keep running.
6. Select **Start > Programs > Windows NT Explorer**.
    - Opens the Windows Explorer panel.
7. Open the Logfile folder.
    a) Click the **C** directory.
    b) Click the **NeuroActivator** folder.
    c) Click the **Logfiles** folder.
8. Select the files you want to remove.
    - Logfiles are listed by type, month, day and year (ttmmddyyyy).

Quick Steps: Remove Selected Logfiles

1. Click **[Manage System]**.
2. Click **[Open Console to Stimulus System]**.
3. Position your cursor in the console window.
4. Right-click on the **NeuroActivator** icon.
5. Click **[Exit]**.
6. Select **Start > Programs > Windows NT Explorer**.
7. Open the Logfile folder.
8. Select the files you want to remove.
9. Click **[File]**.
10. Select **File > Delete**.
11. Click **[Yes]**.
12. Right-click on the **Recycle Bin** icon.
13. Click **[Empty Recycle Bin]**.
14. Select **File > Close**.
15. Select **Start > Programs > NeuroActivator > Clinical**.
16. Click **[Close Console to Stimulus System]**.
17. Click **[Return to Main Menu]**.

a) Press **Shift** and click to select a consecutive range of files.

b) Press **Ctrl** and click to select additional non-consecutive files.

9. Click **[File]**.
   - This is located at the top of the Windows Explorer panel.
10. Select **File > Delete**.
    - This opens a confirmation message window.
11. Click **[Yes]**.
    - This removes all selected logfiles.
12. Right-click on the **Recycle Bin** icon.
    - This is located on the left panel of the Windows Explorer.
13. Click **[Empty Recycle Bin]**.
    - This completely deletes the logfiles from the Stimulus PC disk.
14. Select **File > Close**.
    - This exits the Windows Explorer.
15. Select **Start > Programs > NeuroActivator > NeuroActivator Clinical**.
    - This restarts the NeuroActivator application.
    - The “four boxes” display returns.
16. Click **[Close Console to Stimulus System]**.
    - This exits the console window.
17. Click **[Return to Main Menu]**.
    - This displays the BrainWave Main Menu.

Chapter 9

Visualize fMRI Data

Introduction

BrainWave Visualizer is the visualization software included in the optional Functional Magnetic Resonance Imaging (fMRI) package. This software is located on your Advantage Windows (AW) 4.0 workstation. BrainWave Visualizer allows you to interactively view and edit fMRI data. It is important you read and understand the Functional Magnetic Resonance Imaging chapter before you use the visualization tool.

This chapter explains the BrainWave Visualizer fMRI visualization tool. It also provides the step-by-step instructions to help you learn how to:

- Adjust the Volume Rendering View
- Adjust the Lightbox View

In addition, this chapter answers the following questions:

1. What is a Volume Rendering View?
2. What is a Lightbox View?
3. How do you modify imaging views?
4. What are the quick keyboard functions?

What Do I Need to Know About...

This section presents the concepts necessary to successfully understand the BrainWave Visualizer fMRI visualization tool. Specifically, you need to understand:

- BrainWave Visualizer Basics
  - Transfer Functions
- BrainWave Visualizer Interface
  - Main Menu Bar
  - Control Panel
  - Volume Rendering View
  - Image Display Views
  - Lightbox View
  - Message Area
  - Progress Area
- Volume Rendering View Interactions
  - Window Properties
  - View Properties
  - Volume Appearance Properties
  - Volume Features Properties
- Lightbox View Interactions
  - Window Properties
  - View Properties
  - Image Features Properties

BrainWave Visualizer Basics

BrainWave Visualizer is the volume rendering tool of the BrainWave™ software that interactively displays fMRI data. This tool allows the transformation of the three-dimensional (3D) volume fMRI data into an image. The conversion of the volume into an image can be accomplished with a variety of volume rendering techniques. Most volume rendering techniques essentially perform the same function, but use different methods.

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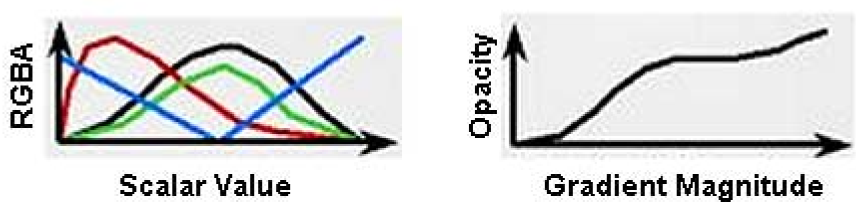
Transfer Functions

The actual image appearance depends on a transfer function that relates voxel values into color and opacity and the material properties of the volume. For example, if you have an fMRI dataset containing bone and skin, you must identify transfer functions that map color and opacity to these features based on properties of the dataset. Scalar value can be grouped into color (red, green, blue) and alpha (opacity), also referred to as RGBA. Scalar value opacity transfer functions are useful for narrowing the range of scalar values that are rendered. The mapping of the gradient value magnitude to an opacity is also a useful transfer function for highlighting areas of sharp change. The final opacity is determined by multiplying the scalar value opacity by the gradient magnitude opacity (Figure 9-1). Your selection of transfer functions affects the final image produced from the fMRI dataset.

Figure 9-1 Transfer Functions



Blending functions consider the scalar values that are mapped to a pixel on the image. They result in a final pixel value that corresponds to the color and opacity transfer functions, the shading information, the interpolation type, and the gradients. Each specific blending function identifies how these values are combined in order to produce the final pixel value. Maximum intensity blending functions consider the scalar values and select the maximum value.

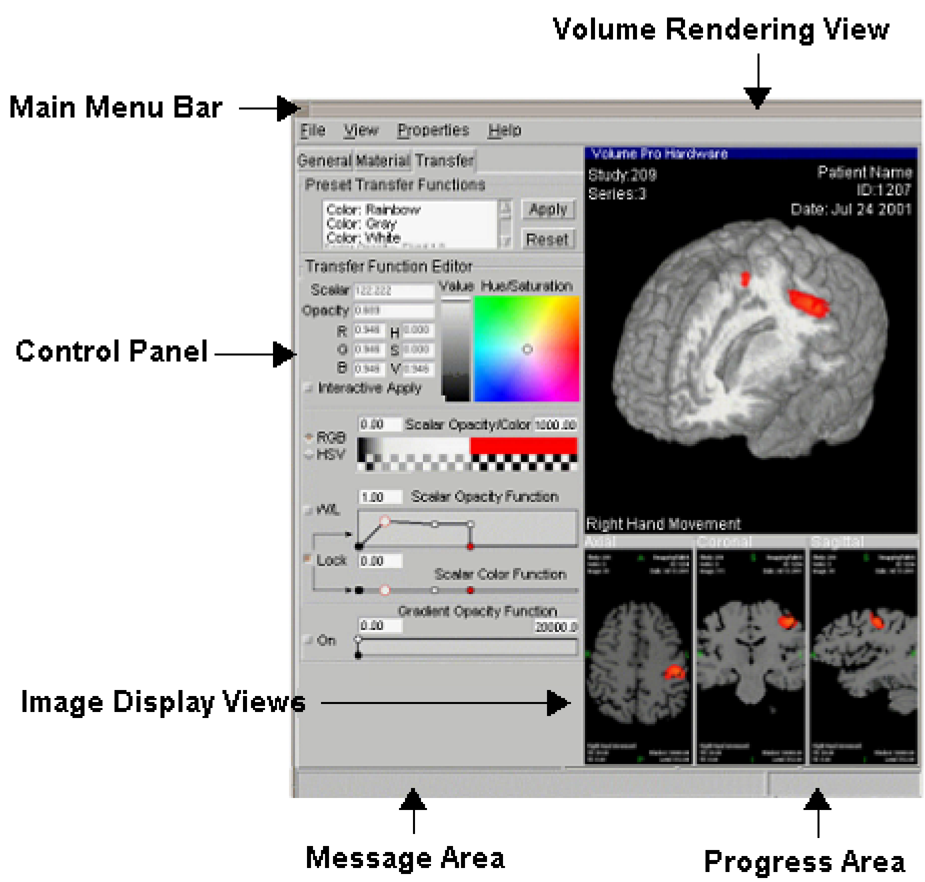
BrainWave Visualizer Interface

The BrainWave Visualizer interface consists of different areas that allow you to interact with the software.

- Main Menu Bar
- Control Panel
- Volume Rendering View
- Image Display Views
- Lightbox View
- Message Area
- Progress Area

Figure 9-2 represents the default configuration of BrainWave Visualizer when a volume is loaded. In the default configuration, all areas are visual except the Lightbox View. This view can be displayed in place of the 3D Volume Rendering and Image Display views by selecting Lightbox from the View options on the Main Menu bar.

Figure 9-2 BrainWave Visualizer Interface



Main Menu Bar

The Main Menu bar in the BrainWave Visualizer is always visible and contains the following basic options:

- File – allows you to print the file as a postscript or exit the application.
- View – allows you to control the layout of the image display views, which are the 3D Volume Rendering View, the Image Display Views, and the Lightbox View.
- Properties – allows you to manage the control panel. The options available are dependent on the currently selected window.

- Help – allows you to display basic information about the BrainWave Visualizer.

Control Panel

The control panel contains the selections for various data and viewing properties such as the transfer functions, window and level, and annotation. The control panel display depends on the selected property on the **Properties** menu.

Volume Rendering View

The Volume Rendering View displays a 3D view of the currently loaded fMRI data. Clicking the title bar of this viewer makes it active. Once active, the **Properties** menu on the Main Menu bar can be used to control which control panel is displayed.

Image Display Views

The Image Display Views presents two-dimensional (2D) views of orthogonal slices of the 3D volume. Either one or three Image Display Views can be visible, depending on the settings selected in the View options on the Main Menu bar. The three views represent the axial, coronal, and sagittal slices of the 3D volume.

Lightbox View

The Lightbox View displays a 2D view of a grid of orthogonal slices of the 3D volume. The control panel associated with this view can be used to select a 2x2, 3x2, or a 3x3 layout with the axial, coronal, or sagittal slices. The control panel displayed depends on your selections from the **Properties** menu on the Main Menu bar when this view is active.

NOTE: If this View is displayed, you will not see the Volume Rendering View and Image Display View areas.

Message Area

The Message area is always visible and displays information such as image cursor position, underlying scalar value, and measurement values.

Progress Area

The Progress area is always visible and displays the ongoing advancement status during some time consuming operations, such as loading data.

Volume Rendering View Interactions

You are able to control the motion of the camera when you activate the Volume Rendering View by clicking the title bar of the viewer. An active view means the control panel options for that view are available in the **Properties** menu, and the print and save functions are operable for that view. There are five properties within the Volume Rendering View. Each property display contains tabs of adjustable imaging functions. Table 9-1 provides a list of the properties for the 3D Volume Rendering View and the tabs presented in each area.

Table 9-1 Volume Rendering View Properties

Properties	Control Panel Display
Hide	Closes the control panel.
Window	Displays the **Layout** and **Preferences** tabs.
View	Displays the **General** and **Annotate** tabs.
Volume Appearance	Displays the **General**, **Material**, and **Transfer** tabs.
Volume Features	Displays the **Cut** and **Annotate** tabs.

Window Properties

When you select Window from the **Properties** menu, the **Layout** and **Preferences** tabs appear in the control panel. These tabs allow you to choose the layout configuration and image preferences of the views.

Layout Tab

There are three basic configurations for the Volume Rendering View layout:

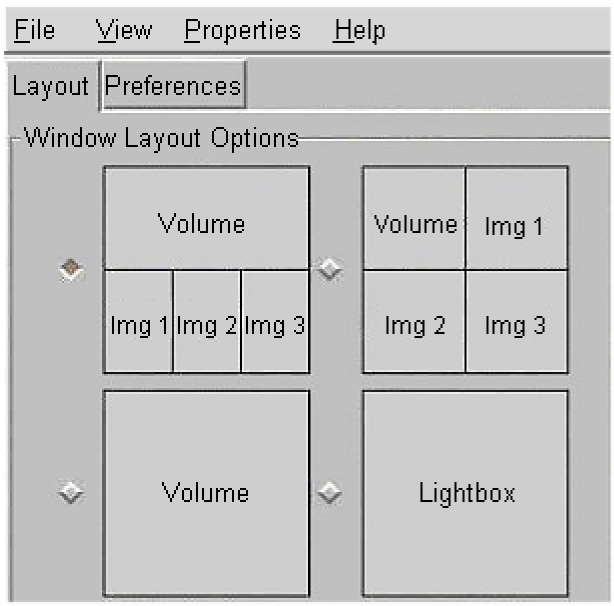
- Volume Only – one Volume Rendering View
- One and Three – one Volume Rendering View above three Image Display Views
- Two by Two – one Volume Rendering View with Image Display Views in a 2x2 format

NOTE: The Lightbox selection in the Window layout options opens the Lightbox View, which does not allow volume rendering. Refer to the Lightbox View Interactions section for the layout options.

You may select the window configuration by choosing a selection from the **View** menu on the Main Menu bar (Figure 9-3) or from the **Layout** tab (Figure 9-4), located in the control panel when the Window property is selected.

Figure 9-3 View Layout Selections

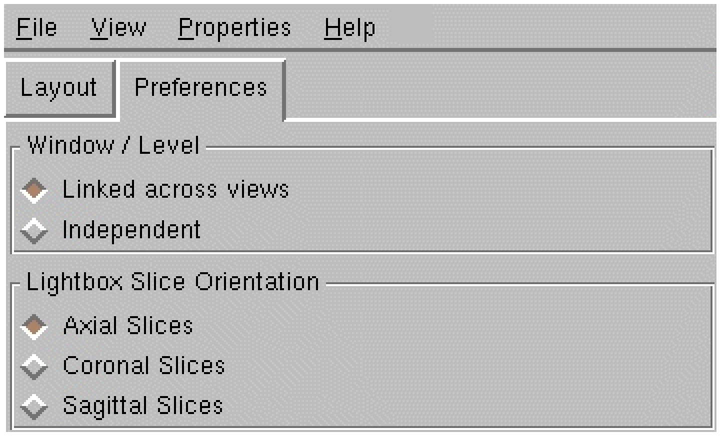
Figure 9-4 Window Layout Tab



Preferences Tab

Image view options, such as window and leveling and slice orientation, are selected from the **Preferences** tab (Figure 9-5). The window and level operations may either be simultaneously linked across all image viewports or independent in each viewport. The orientation of the slices in the Lightbox View allows you to display all axial, coronal, or sagittal slices within the orthogonal viewports.

Figure 9-5 Window Preferences Tab



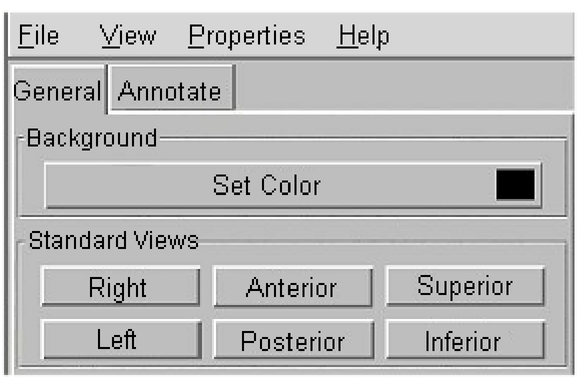
View Properties

When you select View from the **Properties** menu, the control panel of the displays two tabs, **General** and **Annotate**. View properties are used to control the appearance of your viewports.

General Tab

The View **General** tab (Figure 9-6) allows you to change the background color and select standard views using the Right, Anterior, Superior (RAS) coordinate system.

Figure 9-6 View General Tab



You use the **[Set Color]** button to set the background color of the Volume Rendering View. You select the desired color from a color palette in the Choose Color window. The **[OK]** button accepts your color choice, displays it on the Set Color button, and applies the color to the background of the Volume Rendering View.

There are six standard views representing the view down each of the major axes: Right, Left, Anterior, Posterior, Superior, and Inferior. These are viewing positions rather than viewing directions. For example, the **[Right]** button is a view from the right side of the volume, looking down towards the left.

Annotate Tab

There are two annotation types on the **Annotate** tab (Figure 9-7), custom and system specific annotation. Table 9-2 provides a description of the available options.

Figure 9-7 Annotate Tab

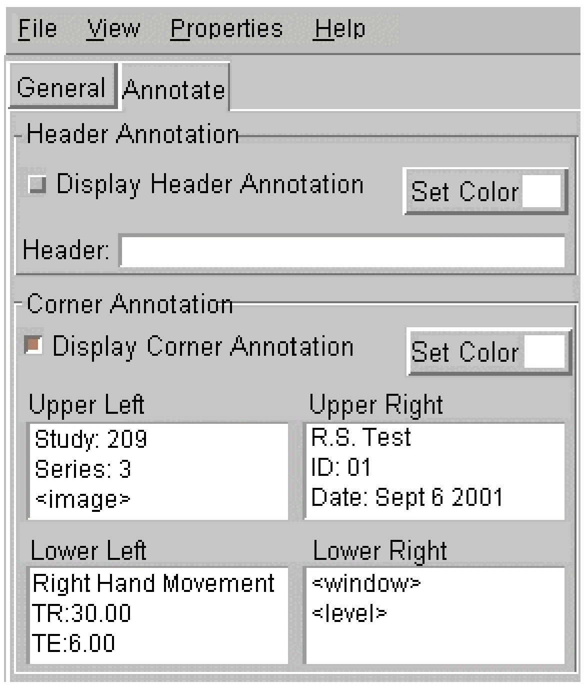


Table 9-2 View Annotate Tab Options

Option	Description
Header Annotation	
Display Header Annotation	Displays or hides a single line of text at the top center of the viewer. The text is entered in the **Header** text box. The annotation scales based on the length of the text.
[Set Color]	Opens the **Choose Color** window, allowing you to move the arrow sliders to change the header annotation color.
Header	Allows you to enter custom Header annotation in the text box.

Option	Description
Corner Annotation	
Display Corner Annotation	Displays four multi-line text items in the corners of the viewer when that viewer is active. Clicking the title bar activates that view. A corner can remain blank.
[Set Color]	Opens the **Choose Color** window, allowing you to move the arrow sliders to change the color of the corner annotation. All corner annotation is the same color.

Volume Appearance Properties

When you select Volume Appearance from the **Properties** menu, the **General**, **Material**, and **Transfer** tabs appear in the control panel. These properties include options on the blending function, super sampling, material properties, and transfer functions. You can adjust these properties to control the appearance of the fMRI data.

General Tab

The Volume Appearance **General** tab (Figure 9-8) displays helpful information about the volume that can be used to control rendering properties for the volume. This tab is divided into four main areas:

- Volume Information – displays information about the size of voxels, units, data origin, and scalar range.
- Level-of-Detail control – allows speed adjustments verses image quality trade-offs.
- Blending Function – provides options on which pixels contribute to the imaging volume.
- Super Sampling – allows the appearance of the image resolution to be slightly enhanced at the expense of rendering time.

Figure 9-8 Volume Appearance General Tab

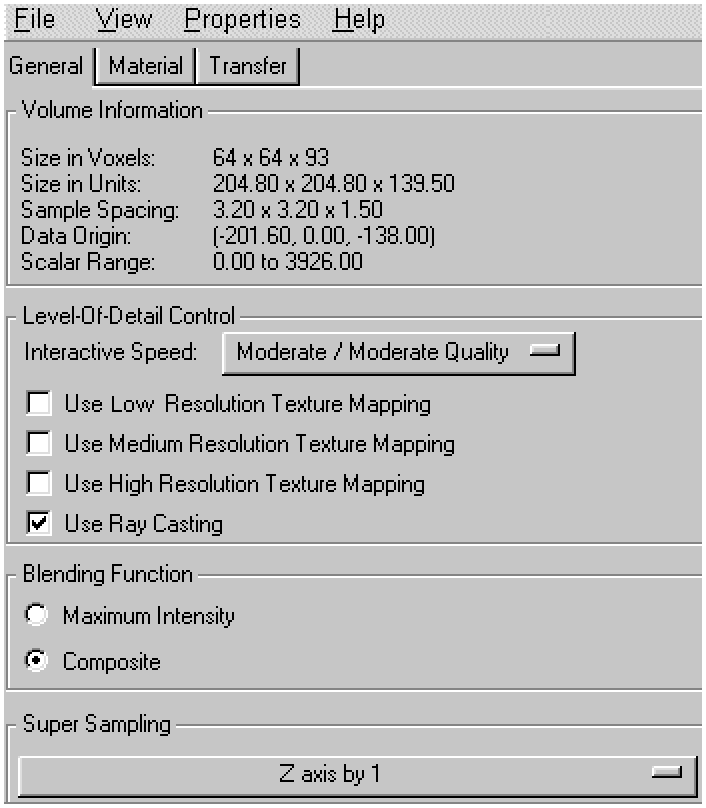


Table 9-3 provides a description of the options located in the Volume Appearance **General** tab.

Table 9-3 Volume Appearance General Tab Options

Options	Descriptions
Volume Information	
Size in Voxels	Indicates the image matrix used.
Size in Units	Indicates the image field of view (FOV) in the X, Y, and Z directions.
Sample Spacing	Indicates the resolution values in the X, Y, and Z directions.
Data Origin	Indicates the position of the cursor.
Scalar Range	Indicates the minimum and maximum color scalar units.

Options	Descriptions
Level-of-Detail Control	
Interactive Speed	Provides a shortcut list of three volume rendering viewing speeds. The faster the speed, the lower the image quality.
Use Low Resolution Texture Mapping	Provides a low detail level of the texture mapping function. Images are displayed with a low resolution texture while being moved.
Use Medium Resolution Texture Mapping	Provides an intermediate detail level of the texture mapping function. Images are displayed with a medium resolution texture immediately after image movement stops.
Use High Resolution Texture Mapping	Provides a higher detail level of the texture mapping function. Images are displayed with a high resolution texture a few seconds after image movement stops.
Use Ray Casting	Provides the highest detail level of the texture mapping function. Images are displayed with the highest resolution after image movement stops. This may take a while to display.
Blending Function	
Maximum Intensity	Displays volume image using only the highest intensity pixels.
Composite	Displays volume image fused with images taken at the same image location.
Super Sampling	
[Z axis by 1] **[Z axis by 2]** **[Z axis by 4]**	Enhances the existing slice direction resolution by factors of 1, 2, and 4.

NOTE: The Volume Appearance **General** tab should not be confused with the **General** tab in the View properties of the control panel. These two tabs have different functions.

Material Tab

The Volume Appearance **Material** tab (Figure 9-9) provides options for adjusting how the imaging volume reflects light. Table 9-4 provides a description of these options.

Figure 9-9 Volume Appearance Material Tab

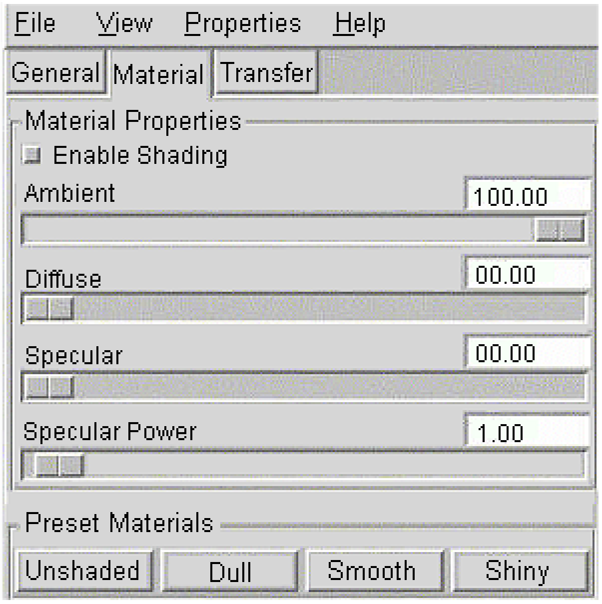


Table 9-4 Volume Appearance Material Tab Options

Option	Description
Material Properties	
Enable Shading	Activates the shading option.
Ambient	Indicates the lighting ambient coefficient value. Acceptable values range from 0 to 100.
Diffuse	Indicates the lighting diffuse coefficient value. Acceptable values range from 0 to 100.
Specular	Indicates the lighting specular coefficient value. Acceptable values range from 0 to 100.
Specular Power	Indicates the lighting specular power. Acceptable values range from 0 to 50.
Preset Materials	
[Unshaded]	Applies a pre-defined, non-shaded light setting.
[Dull]	Applies a pre-defined, dull appearance light setting.
[Smooth]	Applies a pre-defined, smooth light setting.
[Shiny]	Applies a pre-defined, shiny light setting.

Transfer Tab

The Volume Appearance **Transfer** tab (Figure 9-10) includes color and opacity functions used by the functional maps to influence the appearance of the final image. The functions on this tab are the most difficult to set because the adjustments are data dependent and must be performed manually. There are three transfer functions that affect the rendering process.

- Color transfer functions – converts the scalar data into red, green, and blue (RGB) colors.
- Opacity transfer function – converts the scalar data into alpha (transparency) values.
- Gradient transfer function – converts the magnitude of the gradient, (rate of change in the scalar data) into opacities.

The color and opacity transfer functions are useful for making material imaging changes, while the gradient transfer function is applicable for enhancing the edges of the imaging volume.

The **Transfer** tab is divided into two main areas, Preset Transfer Functions and Transfer Function Editor. The Preset Transfer Functions area allows you to choose preset color maps, an opacity ramp, and a gradient magnitude. There are three color map options: Rainbow, Gray, and White. Linear and Solid are the two opacity ramp options provided. You also have the option to vary the edge detection settings on the image volume.

The Transfer Function Editor allows you to create transfer functions to display the data. Values can be entered numerically or by making scalar graph adjustments. Within each graph, at least two nodes are displayed. Additional nodes may be added. You can activate and move the nodes to make transfer adjustments. An activated node is represented by an enlarged node surrounded by a red circle (Figure 9-10).

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Figure 9-10 Volume Appearance Transfer Tab

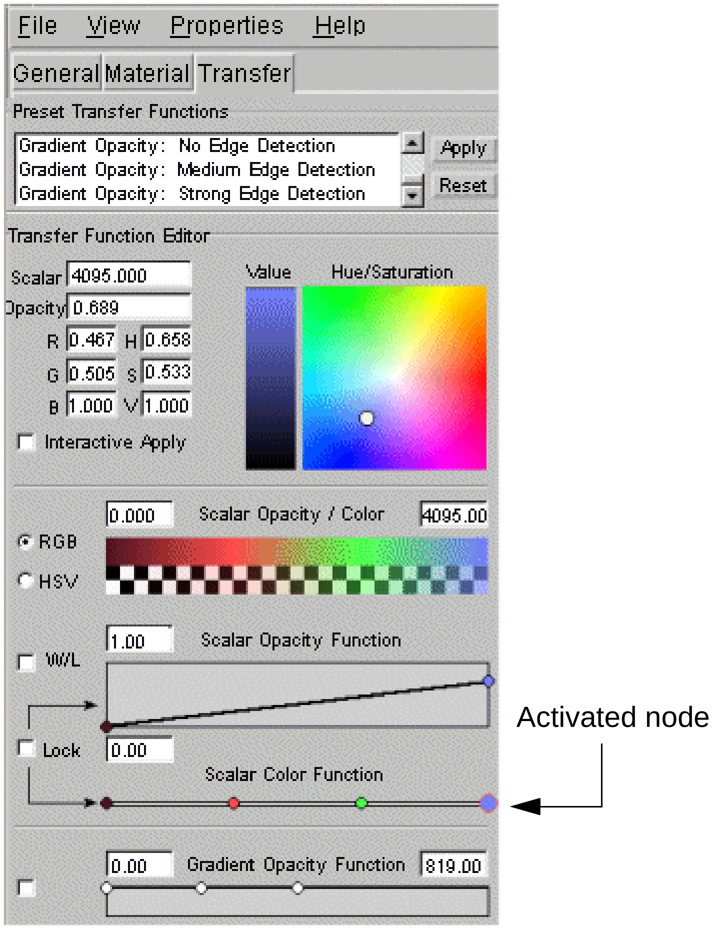


Table 9-5 describes the Volume Appearance **Transfer** tab available options.

Table 9-5 Volume Appearance Transfer Tab Options

Options	Descriptions
Preset Transfer Functions	
Color	Provides pre-defined color ramp settings for Rainbow, Gray, or White.
Scalar Opacity	Provides pre-defined opacity linear ramp settings for a ramp ranging from 0.0 to 0.2, a ramp ranging from 0.0 to 1.0, and a solid opaque function (fixed 1.0).
Gradient Opacity	Provides pre-defined gradient magnitude settings for no edge detection, medium edge detection, or strong edge detection.
[Apply]	Displays the selected color, scalar opacity, and/or gradient opacity pre-defined settings.

Options	Descriptions
[Reset]	Returns the imaging volume to its original settings.
	Transfer Function Editor
Scalar	Establishes the scalar value of the current node. The value range is 0 to 1.
Opacity	Establishes the opacity value of the current node. The value range is 0 to 1.
R,G,B,H,S,V	Indicates the respective value (red, green, blue, hue, saturation, value factor) of the current node. The acceptable range of values are from 0 to 1.
Interactive Apply	Applies function changes immediately to the imaging volume.
Value	Displays the current node's value color scale.
Hue/Saturation	Displays the current node's hue and saturation color palette.
Scalar Opacity/Color	Left text box represents the minimum scalar value, located on the left edge of the color spectrum. Right text box represents the maximum scalar value, located on the right edge of the color spectrum.
RGB	Interpolates colors in the red, green, and blue color scale.
HSV	Interpolates colors in the hue, saturation, and value color scale.
Scalar Opacity Function	Top text box indicates the maximum opacity value, represented by the top edge of the scalar opacity function. Bottom text box indicates the minimum opacity value, represented by the bottom edge of the scalar opacity function.
W/L	Activates the window and level mode for opacity editing.
Lock	Combines the color and opacity functions.
Scalar Color Function	Displays the Scalar Color Function bar.
Gradient Opacity Function	Left text box indicates the minimum gradient magnitude value represented by the left edge of the gradient opacity function. The right text box indicates the maximum gradient magnitude value represented by the right edge of the gradient opacity function.
On	Activates the gradient modulation function.

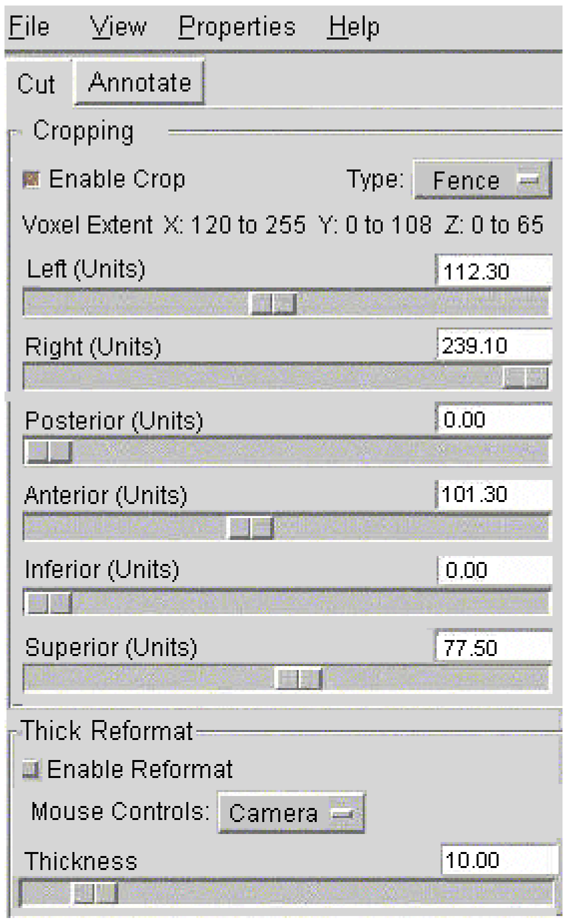
Volume Features Properties

The Volume Features option allows you to cut (crop) and reformat your imaging volume. Annotation can be displayed or removed from selected viewports. When you select Volume Features from the **Properties** menu, the **Cut** and **Annotate** tabs appear on the control panel.

Cut Tab

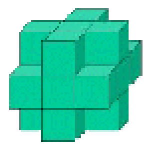
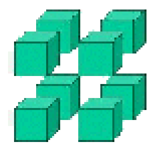
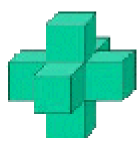
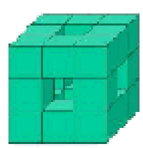
The Volume Features **Cut** tab (Figure 9-11) allows you to crop and reformat your imaging volume.

Figure 9-11 Volume Features Cut Tab



You can apply orthogonal cuts to the imaging volume by using the **Enable Crop** option. Cuts are made by adjusting the six imaging sliders and selecting a cropping type. There are five cropping types (Table 9-6) in the **Type** pull-down menu.

Table 9-6 Volume Features Cropping Types

Cropping Type	Description
Subvolume 	Allows only voxel cuts defined by the imaging sliders. This type is the system default and the volume is interactively updated as the cropping sliders are moved.
Fence 	Alters a portion of the volume between any pair of orthogonal planes by removing the corner of the imaging volume.
Inverted Fence 	Alters a portion of the volume outside of the orthogonal planes. This is the reverse action of the Fence operation. Instead of removing the imaging corners, the corners are the only portion of the imaging volume displayed.
Cross 	Removes the outer voxels, leaving the portion of the volume that is between any two pair of orthogonal planes. This displays a cross imaging effect.
Inverted Cross 	Displays the portion of the volume outside of the two orthogonal planes, while the inner voxels (cross) are removed. This is the reverse operation of the Cross cropping type.

When using any crop type other than Subvolume, a minimum of three orthogonal sliders must be moved in order to crop the volume. If you select Subvolume as the crop type, then only a minimum of one slider is needed to crop the volume.

Figure 9-12 displays images with each cropping type applied. The sliders (Figure 9-13) are in the same position for each image to illustrate the difference.

Figure 9-12 Images of Cropping Types

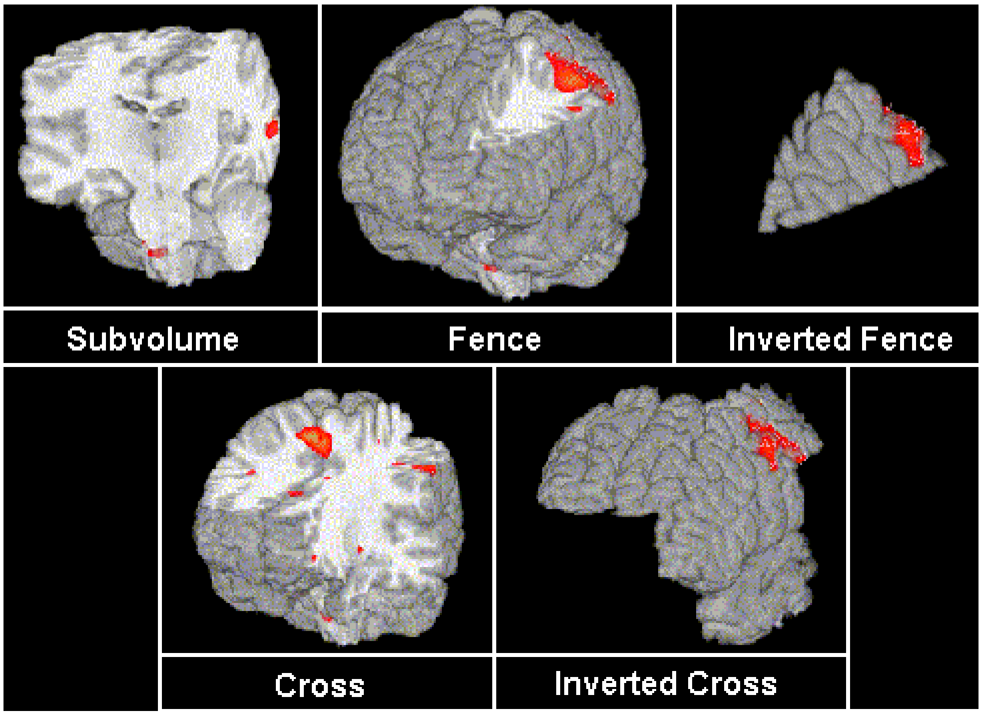
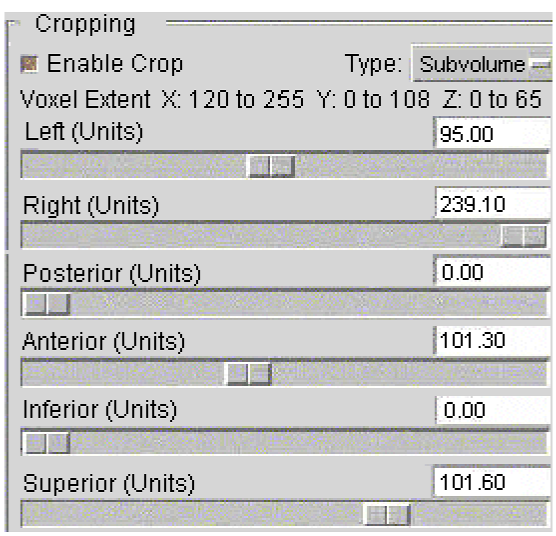


Figure 9-13 Cropping Sliders



Thick reformat is the process of slicing the volume with a slab. The Thick Reformat mode is activated on the **Cut** tab (Figure 9-11) with the **Enable Reformat** option. The thickness of the slab can be controlled by adjusting the Thickness slider. The **Mouse Controls** menu provides two options for how you use the mouse to manipulate your image. Camera is used for the normal reformatting mode. Reformat allows you to rotate the image using the mouse.

Annotation Tab

The Volume Feature **Annotate** tab includes several annotation and coloring options. Various cursor types can also be included. Figure 9-14 displays the **Annotate** tab and Table 9-7 provides a description of the options.

NOTE: The **Annotate** tab (Figure 9-14) should not be confused with the **Annotate** tab in the View property control panel. These two tabs have different functions.

Figure 9-14 Volume Features AnnotateTab

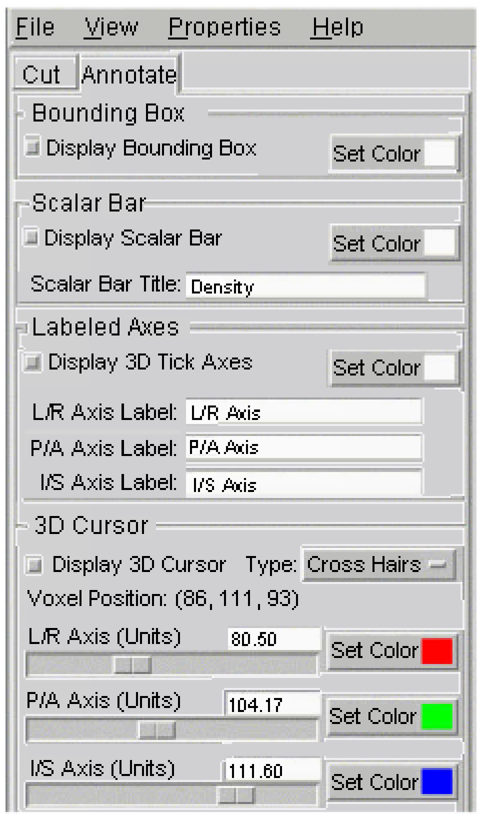


Table 9-7 Volume Features Annotate Tab Options

Option	Description
[Set Color]	Opens the **Choose Color** window, allowing color changes to be made to the respective function. All **[Set Color]** buttons on this tab have the same functionality.

Option	Description
Bounding Box	
Display Bounding Box	Shows a 3D interactive box.
Scalar Bar	
Display Scalar Bar	Posts a scalar bar on the right side of the volume viewport showing the range of colors in the activation map. The color corresponds to a numeric value that indicates the confidence of true activation. A color corresponding to a lower number indicates less confidence of true activation.
Scalar Bar Title	Allows you to display a custom title over the Scalar Bar.
Labeled Axes	
Display 3D Tick Axes	Displays the 3D Tick Axes in X, Y coordinates of a structure as it relates to its position in the volume. For example, if you move the S/I slider to a desired structure, the number on the slider represents the number of millimeters from the bottom of the volume.
L/R Axis Label	Allows you to enter a custom axis label for the left and right axes.
P/A Axis Label	Allows you to enter a custom axis label for the posterior and anterior axes.
I/S Axis Label	Allows you to enter a custom axis label for the inferior and superior axes.
3D Cursor	
Display 3D Cursor	Shows one of two 3D Cursors. Cursor options are selected via the **Type** pull-down menu.
Type	Allows selection of cross-hair and plane cursor types.
L/R Axis	Adjusts the 3D Cursor in the left and right imaging directions.
P/A Axis	Adjusts the 3D Cursor in the posterior and anterior imaging directions.
I/S Axis	Adjusts the 3D Cursor in the inferior and superior imaging directions.

Lightbox View Interactions

The Lightbox View provides an alternative method for viewing your fMRI data. In order to see the Lightbox, you must have the lightbox layout option selected from the **View** menu or **Layout** tab. When Lightbox is the current layout option, it is automatically active since it is the only available view. You can select the Lightbox properties from the **Properties** menu on the Main Menu bar.

This view only displays 2D orthogonal images. Images can be axial, coronal, and sagittal slices of the 3D volume. There are three main properties within this type of view. Each property display contains tabs of adjustable imaging functions. Table 9-8 provides a list of the properties for the Lightbox View and the tabs presented in each area.

Table 9-8 Lightbox View Properties

Properties	Control Panel Display
Hide	Closes the control panel.
Window	Displays the **Layout** and **Preferences** tabs.
View	Displays the **General** and **Annotate** tabs.
Image Features	Displays image feature functions.

Window Properties

When you select Window from the **Properties** menu, the **Layout** and **Preferences** tabs appear in the control panel. Similar to the 3D Volume Rendering View, these tabs allow you to choose the layout configuration and image preferences of the views.

Layout Tab

The Lightbox View has several different layout formats (Figure 9-15) that can only be used by this viewer. Layouts include a four, six, and nine viewport setting. The images being displayed are either all axial, sagittal or coronal.

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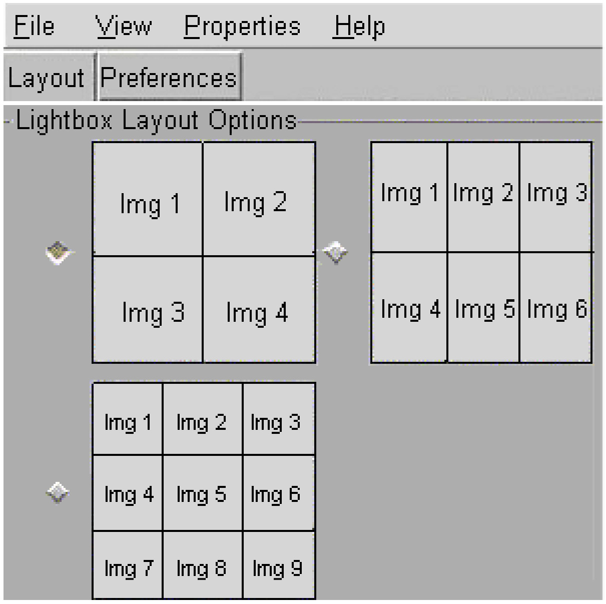
Figure 9-15 Lightbox Layout Options Area



Preferences Tab

Image view options, such as window and leveling and slice orientation, are selected from the Lightbox View **Preferences** tab.

NOTE: Refer to the Preferences Tab section in the Volume Rendering View Interactions section. These preferences are identical for the Lightbox View.

View Properties

When you select View from the **Properties** menu, the **General** tab displays in the control panel.

General Tab

The Lightbox View **General** tab allows you to control the background color of the Lightbox View with the **[Set Color]** option. A **Choose Color** window is displayed, allowing you to choose the background color. Once you select a new color, that color displays on the **[Set Color]** button.

Figure 9-16 General Tab

Annotate Tab

There are two annotation types on the **Annotate** tab, custom and system specific annotation.

NOTE: Refer to Annotation Tab in the Volume Rendering Interactions section. The annotation options for the Lightbox View are identical.

Image Features Properties

When you select Image Features from the **Properties** menu, the control panel allows you to control various image features such as slice locations, window and leveling settings, mouse controls, image color and probe (cursor) information. Figure 9-17 displays the Image Features property window and Table 9-9 provides a description of the options.

Figure 9-17 Image Features Properties

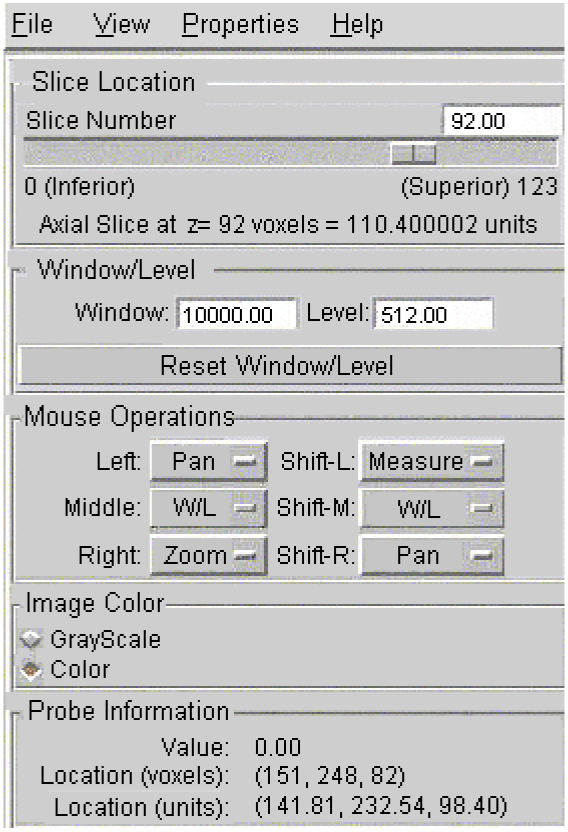


Table 9-9 Image Feature Options

Option	Description
Slice Location	
Slice Number	Indicates the image number displayed within the viewer in voxels and units. You can enter a number in the text box or use the slider to control the slice number.
Window/Level	
Window	Indicates your image windowing factor.
Level	Indicates your image leveling factor.
[Reset Window/Level]	Returns the window and leveling values to the original setting.
Mouse Operations	
Left **Middle** **Right**	Defines the function of the left, middle, and right mouse buttons. The options are Pan, W/L (window/level), Zoom, and Measure.

Option	Description
Shift-L **Shift-M** **Shift-R**	Provides additional mouse button functionality by pressing the **Shift** key and the desired mouse button at the same. For example, **Shift-L** defines the function when you press Shift and the left mouse button. The options are Pan, W/L (window/level), Zoom, and Measure.
Image Color	
GrayScale	Displays the functional activity in various shades of gray.
Color	Displays the functional activity in color.
Probe Information	
Value	Displays the scalar value of the image pixel on which the cursor is placed.
Location	Displays the location (in voxels and units) of the image pixel on which the cursor is placed.

How Do I...

This section provides the step-by-step instructions for rendering images to visualize white matter tracts. Specifically, it describes how to:

- Adjust the Volume Rendering View
  - Control the Hide and Window Properties
  - Control the Volume Features Properties
  - Control the Volume Appearance Properties
  - Control the Volume Features Properties
  - Manipulate the Volume
- Adjust the Lightbox View
  - Control the Hide and Window Properties
  - Control the View Properties
  - Control the Image Features Properties

NOTE: Prior to performing the tasks in this chapter, you should acquire and perform an fMRI exam. Use the Visualize fMRI Data instructions, located in the Functional Magnetic Resonance Imaging chapter to open the BrainWave Visualizer application of the BrainWave software.

Quick Steps: Control the Hide and Window Properties

1. Select the desired layout from the **View** menu.
2. Select **Properties > Hide Properties**.
3. Select **Properties > Window**.
4. Select the **Preferences** tab to move it forward.
5. Select the desired window and level settings.

Adjust the Volume Rendering View

Control the Hide and Window Properties

After your fMR images have been processed and analyzed, they can be displayed in the Volume Rendering View with the BrainWave Visualizer tool. There are several Volume Rendering properties that can be adjusted to your personal preference.

1. Select the desired layout from the **View** menu.
   - Volume Only – one Volume Rendering View
   - One and Three – one Volume Rendering View above three Image Display Views
   - Two by Two – one Volume Rendering View with Image Display Views in a 2x2 format
2. Select **Properties > Hide Properties**.
   - This hides the control panel, maximizing the visualization area.
3. Select **Properties > Window**.
   - The **Layout** and **Preferences** tabs display in the control panel.
4. Select the **Preferences** tab to move it forward.
5. Select the desired window and level settings.
   - Linked across views automatically adjusts all viewports to the same window and level setting.
   - Independent only adjusts the window and level setting for the viewport your mouse is located.

Adjust the Volume Rendering View

Control the View Properties

The View properties of the Volume Rendering View display the **General** and **Annotate** tabs in the control panel. These properties allow you to control the appearance of your viewports by performing the following functions:

- Change the Background Color
- Select a Standard View
- Annotate the Volume

Change the Background Color of the Volume

Use this procedure to select the background color for the Volume Rendering View.

1. Select **Properties > View**.
   - The control panel displays the **General** and **Annotate** tabs.
2. Select the **General** tab to move it forward.
3. Click **[Set Color]**.
   - The Choose Color window displays.
4. Select the desired color for the background from the color palette.
5. Click **[OK]**.
   - The background color updates to your selection on the image view.

Select a Standard View

Use this procedure to select a standard orthogonal axis view.

1. Select **Properties > View**.
   - The control panel displays the **General** and **Annotate** tabs.
2. Select the **General** tab to move it forward.

Quick Steps: Control the View Properties

Change the Background Color of the Volume

1. Select **Properties > View**.
2. Select the **General** tab to move it forward.
3. Click **[Set Color]**.
4. Select the desired color for the background from the color palette.
5. Click **[OK]**.

Select a Standard View

1. Select **Properties > View**.
2. Select the **General** tab to move it forward.
3. Click the desired orthogonal axis view.

Annotate the Volume

1. Select **Properties > View**.
2. Select the **Annotate** tab to move it forward.
3. Select **Display Header Annotation**.
4. Enter your desired text in the **Header** text box.
5. Click **[Set Color]**.
6. Select the desired color for text display from the color palette.
7. Click **[OK]**.

3. Click the desired orthogonal axis view.
   - There are six standard views representing the view down each of the major axes: right, left, anterior, posterior, superior, and inferior.
   - These are viewing positions rather than viewing directions.

Annotate the Image

Use this procedure to modify the Header and Corner Annotation function by adjusting the text color and annotation views.

1. Select **Properties > View**.
   - The control panel displays the **General** and **Annotate** tabs.
2. Select the **Annotate** tab to move it forward.
3. Select **Display Header Annotation**.
4. Enter your desired text in the **Header** text box.
   - The annotation displays at the top center of the view.
   - The annotation scales in size based on the length of the text.
5. Click **[Set Color]**.
   - The Choose Color window displays.
6. Select the desired color for text display from the color palette.
   - Alternatively, you may click and drag the + (cursor) to select your desired color.
7. Click **[OK]**.
   - The Choose Color window closes.
   - The text displays in the viewport and prints, if you have a color printer.

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Adjust the Volume Rendering View

Control the Volume Appearance Properties

You can adjust the shading and transfer functions to control the appearance of the fMRI data. For your ease, the Volume Appearance properties have been divided into the following sections:

- Adjust the Image Shading
- Select Preset Transfer Functions
- Create Custom Color and Opacity Transfer Functions
- Create Custom Gradient Transfer Functions

Adjust the Image Shading

The Material options allow you to adjust your image shading by choosing pre-defined shading materials or creating your own.

1. Select **Properties > Volume Appearance**.
   - The control panel displays the **General**, **Material**, and **Transfer** tabs.
2. Select the **Material** tab to move it forward.
3. Select **Enable Shading**.
   - The shading function is activated.
4. Click and drag the shading sliders to adjust the tinting.
   - Imaging sliders include Ambient, Diffuse, Specular, and Specular Power.
   - Dragging the mouse to the left decreases the shading factor, while dragging the mouse to the right increases the shading factor.
     – Alternatively you can enter a shading factor into one of the shading text boxes.
5. Choose a pre-defined shading material.
   - The options are Unshaded, Dull, Smooth, and Shiny.
   - This automatically updates the shading sliders to the selected preset value.

Quick Steps: Control the Volume Appearance Properties

Adjust the Image Shading

1. Select **Properties > Volume Appearance**.
2. Select the **Material** tab.
3. Select **Enable Shading**.
4. Click and drag the shading sliders to adjust the tinting.
5. Choose a pre-defined shading material.

Control the Volume Appearance Properties

Quick Steps: Control the Volume Appearance Properties cont.

Select Preset Transfer Functions

1. Select **Properties > Volume Appearance**.
2. Select the **Transfer** tab to move it forward.
3. Double-click the desired Color in the Preset Transfer Functions area to apply the color settings to your image.
4. Click the down arrow to display the Scalar Opacity options.
5. Double-click the desired Scalar Opacity option to apply the settings to your image.
6. Click the down arrow to display the Gradient Opacity options.
7. Double-click the desired Gradient Opacity option to apply the settings to your image.
8. Click **[Reset]**, if necessary.

Select Preset Transfer Functions

Use this procedure to change the volume appearance by selecting a predefined color transfer function.

1. Select **Properties > Volume Appearance**.
   - The control panel displays the **General**, **Material,** and **Transfer** tabs.
2. Select the **Transfer** tab to move it forward.
3. Double-click the desired Color in the Preset Transfer Functions area to apply the color settings to your image
   - Alternatively, you can use the following method:
     – Click the desired Color transfer function.
     – Click **[Apply]**.
4. Click the down arrow to display the Scalar Opacity options.
   - Fixed 1.0 – linear ramp range set at constant 1.0.
   - Ramp to 0.2 – linear ramp range from 0.0 to 0.2.
   - Ramp to 1.0 – linear ramp range from 0.0 to 1.0.
5. Double-click the desired Scalar Opacity option to apply the settings to your image.
   - Alternatively, you can use the following method:
     – Click the desired Scalar Opacity transfer function.
     – Click **[Apply]**.
6. Click the down arrow to display the Gradient Opacity options.
   - No Edge Detection
   - Medium Edge Detection
   - Strong Edge Detection

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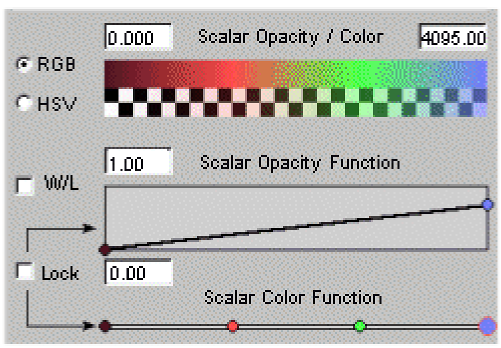
7. Double-click the desired Gradient Opacity option to apply the settings to your image.
   - Alternatively, you can use the following method:
     – Click the desired Gradient Opacity transfer function.
     – Click **[Apply]**.
8. Click **[Reset]**, if necessary.
   - The color settings return to the original setting.
   - Repeat steps 3 through 7 to make new color settings.

Create Custom Color and Opacity Transfer Functions

Use this procedure to manually adjust your color and opacity transfer functions to change the volume appearance.



Scalar Opacity Transfer Function Area

1. Select **RGB** to activate the color spectrum.
   - Alternatively, you can select HSV to activate the hue, saturation, and value color spectrum.
2. Enter a minimum value in the left **Scalar Opacity/Color** text box.
   - This sets the starting range of your color spectrum.
   - The default minimum value is 0.
3. Enter a maximum value in the right **Scalar Opacity/Color** text box.
   - This sets the ending range of your color spectrum.
   - The default maximum value is 4095.

Quick Steps: Control the Volume Appearance Properties cont.

Create Custom Color and Opacity Transfer Functions

1. Select **RGB** to activate the color spectrum.
2. Enter a minimum value in the left **Scalar Opacity/Color** text box.
3. Enter a maximum value in the right **Scalar Opacity/Color** text box.
4. Enter a maximum value in the top **Scalar Opacity Function** text box.
5. Enter a minimum value in the bottom **Scalar Opacity Function** text box.
6. Click the **Scalar Opacity Function** graph line to create additional nodes, if necessary.
7. Click and drag the node to reposition it.

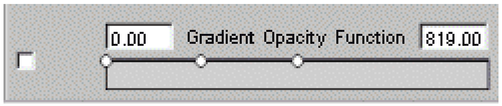
Create Custom Gradient Transfer Functions

1. Enter a minimum value in the left **Gradient Opacity Function** text box.
2. Enter a maximum value in the right **Gradient Opacity Function** text box.
3. Click and drag the node to reposition it.

4. Enter a maximum value in the top **Scalar Opacity Function** text box.
   - This sets the ending range for your opacity function.
   - The default maximum value is 1.
   - The values can be changed in 0.1 increments.
5. Enter a minimum value in the bottom **Scalar Opacity Function** text box.
   - This sets the starting range for your opacity function.
   - The default minimum value is 0.
   - The values can be changed in 0.1 increments.
6. Click the **Scalar Opacity Function** graph line to create additional nodes, if necessary.
   - The node colors are based on the location of where you click the line. This location matches the corresponding area on the color spectrum.
7. Click and drag the node to reposition it.
   - The node increases in size and is surrounded by a red circle.
   - Nodes cannot be moved past another node.

Create Custom Gradient Transfer Functions

Use this procedure to manually adjust the gradient opacity transfer function to change the volume appearance.



Gradient Opacity Transfer Function Area

1. Enter a minimum value in the left **Gradient Opacity Function** text box.
   - Sets the starting range for your gradient opacity function.
   - The defaulted and minimum value is 0.
2. Enter a maximum value in the right **Gradient Opacity Function** text box.
   - Sets the ending range for your opacity function.
   - The defaulted and maximum value is 819.
3. Click and drag the node to reposition it.
   - Nodes cannot be moved past another node.

Adjust the Volume Rendering View

Control the Volume Features Properties

View properties allow you to make cuts and annotation changes to your image volume. For your ease, the volume control features have been separated into two sections:

- Cut and Reformat the Image Volume
- Annotate the Volume Tools

Cut and Reformat the Image Volume

Use this procedure to remove portions of the brain by applying orthogonal cuts to the imaging volume and reformat the image by adjusting the thickness.

1. Select **Properties > Volume Features**.
   - The control panel displays the **Cut** and **Annotate** tabs.
2. Select the **Cut** tab to move it forward.
3. Select **Enable Crop**.
   - This permits image cropping to be performed.
4. Click and drag three Cut sliders toward the middle of the slider bar.
   a) Click and drag either the Left or Right slider.
   b) Click and drag either the Posterior or Anterior slider.
   c) Click and drag either the Inferior to Superior slider.
5. Select the desired cropping type from the **Type** menu.
   - Refer to the Cut Tab section of this chapter for a description of the cropping types.
6. Adjust the Cut sliders to visualize the desired area.
7. Select **Enable Reformat**.
   - This activates the thick reformat feature, allowing you to make oblique slab cuts.

Quick Steps: Control the Volume Features Properties

Cut and Reformat the Image

1. Select **Properties > Volume Features**.
2. Select the **Cut** tab to move it forward.
3. Select **Enable Crop**.
4. Click and drag three Cut sliders toward the middle of the slider bar.
5. Select the desired cropping type from the **Type** menu.
6. Adjust the Cut sliders to visualize the desired area.
7. Select **Enable Reformat**.
8. Click and drag the Thickness slider to adjust the slice thickness.
9. Select an option from the **Mouse Controls** menu.

Quick Steps: Control the Volume Features Properties cont.

Annotate the Volume Tools

1. Select **Properties > Volume Features**.
2. Select the **Annotate** tab to move it forward.
3. Select the 3D Cursor type from the **Type** menu.
4. Select **Display 3D Cursor**.
5. Click and drag the 3D Cursor sliders to adjust the cursor.
6. Click **[Set Color]**.
7. Select the desired color from the color palette.
8. Click **[OK]**.

8. Click and drag the Thickness slider to adjust the slice thickness.
   - Move the slider to the left to decrease slice thickness.
   - Move the slider to the right to increase slice thickness.
9. Select an option from the **Mouse Controls** menu.
   - Camera is the normal reformatting mode.
   - Reformat allows you to rotate with a left-click and move in and out with a right-click.

Annotate the Volume Tools

Use this procedure to select the type and color of cursors for the Volume Rendering View.

1. Select **Properties > Volume Features**.
   - The control panel displays the **Cut** and **Annotate** tabs.
2. Select the **Annotate** tab to move it forward.
3. Select the 3D Cursor type from the **Type** menu.
   - Cross Hairs displays a cross line cursor.
   - Plane displays a square cursor.
4. Select **Display 3D Cursor**.
   - The selected cursor type displays.
5. Click and drag the 3D Cursor sliders to adjust the cursor.
   - The cursor planes move across the volume image and corresponding images at the bottom of the window.
   - Alternatively, you may enter a 3D Cursor position in the appropriate axis text box.
6. Click **[Set Color]**.
   - The Choose Color window displays.
7. Select the desired color from the color palette.
   - Alternatively, you may click and drag the + (cursor) to select your desired color.
8. Click **[OK]**.
   - The Choose Color window closes.
   - The cursor color updates.

Adjust the Volume Rendering View

Manipulate the Volume

There are several viewing options that allow you to adjust the location and size of your 3D volume and perform distance measurements. Use the following procedures to:

- Rotate the 3D Volume
- Pan the 3D Volume
- Zoom the 3D Volume
- Measure a Distance
- Use Keyboard Quick Functions

Rotate the 3D Volume

Use this procedure to manually adjust the volume viewing angles.

1. Place your cursor anywhere on the image.
2. Click and drag the image to rotate it to your desired position.
   - Dragging the mouse from side to side rotates the image from left to right.
   - Dragging the mouse from top to bottom rotates the image inferiorly to superiorly.
   - Dragging the mouse diagonally rotates the image in all directions simultaneously.

Pan the 3D Volume

Use this procedure to reposition your imaging volume in the viewport.

1. Place your cursor anywhere on the image.
2. Middle-click and drag the image to reposition it in the viewport.

Zoom the 3D Volume

Use this procedure to adjust the viewing magnification factors.

1. Place your cursor anywhere on the image.

Quick Steps: Manipulate the Volume

Rotate the 3D Volume

1. Place your cursor anywhere on the image.
2. Click and drag the image to rotate it to your desired position.

Pan the 3D Volume

1. Place your cursor anywhere on the image.
2. Middle-click and drag the image to reposition it in the viewport.

Zoom the 3D Volume

1. Place your cursor anywhere on the image.
2. Right-click and drag to adjust image magnification.

Measure a Distance

1. Click the image at the desired measurement starting point.
2. Drag the measurement line to the desired end point.

Use the Quick Keyboard Functions

1. Press **R** to reset the image to its original settings.
2. Press **P** to update the cursor's position between views.

2. Right-click and drag to adjust image magnification.
   - Dragging the mouse upward increases magnification
   - Dragging the mouse downward decreases magnification.

Measure a Distance

1. Click the image at the desired measurement starting point.
   - The beginning point of measurement is defined.
2. Drag the measurement line to the desired end point.
   - The end point of measurement is defined.
   - The measurement report is given in the Message area.

Use the Quick Keyboard Functions

1. Press **R** to reset the image to its original settings.
2. Press **P** to update the cursor's position between views.

Adjust the Lightbox View

Control the Hide and Window Properties

After your fMR images have been processed and analyzed, they can also be displayed in the Lightbox View with the BrainWave Visualizer tool. There are several Lightbox View properties that can be adjusted to your personal preference.

1. Select **View > Lightbox**.
   - This displays the Lightbox View.
2. Select **Properties > Hide Properties**.
   - The control panel hides, maximizing the visualization area.
3. Select **Properties > Window**.
   - The **Layout** and **Preferences** tabs display in the control panel.
4. Select the **Layout** tab to move it forward.
5. Select the desired viewport layout.
   - 2x2 layout with the axial, coronal, or sagittal slices.
   - 3x2 layout with the axial, coronal, or sagittal slices.
   - 3x3 layout with the axial, coronal, or sagittal slices.
6. Select the **Preferences** tab to move it forward.
7. Select the desired window and level setting.
   - Linked across views automatically adjusts all viewports to the same window and level setting.
   - Independent only adjusts the window and level setting for the viewport your mouse is located.
8. Select the desired slice orientation.
   - Axial Slices – displays all axial slices.
   - Coronal Slices – displays all coronal slices.
   - Sagittal Slices – displays all coronal slices.

Quick Steps: Control the Hide and Window Properties

1. Select **View > Lightbox**.
2. Select **Properties > Hide Properties**.
3. Select **Properties > Window**.
4. Select the **Layout** tab to move it forward.
5. Select the desired viewport layout.
6. Select the **Preferences** tab to move it forward.
7. Select the desired window and level setting.
8. Select the desired slice orientation.

Adjust the Lightbox View

Control the View Properties

Quick Steps: Control the View Properties

Change the Background Color of the Image

1. Select **Properties > View**.
2. Select the **General** tab to move it forward.
3. Click **[Set Color]**.
4. Select the desired color for the background from the color palette.
5. Click **[OK]**.

Annotate the Image

1. Select **Properties > View**.
2. Select the **Annotate** tab to move it forward.
3. Select **Display Header Annotation**.
4. Enter your desired text in the **Header** text box.
5. Click **[Set Color]**.
6. Select the desired color for text display from the color palette.
7. Click **[OK]**.

View properties allow you to select the background color for the Lightbox View and make additional annotation changes. For your ease, the View properties have been separated into two sections:

- Change the Background Color of the Image
- Annotate the Image

Change the Background Color of the Image

Use this procedure to select the background color for the Lightbox View.

1. Select **Properties > View**.
   - The control panel displays the **General** and **Annotate** tabs.
2. Select the **General** tab to move it forward.
3. Click **[Set Color]**.
   - The Choose Color window displays.
4. Select the desired color for the background from the color palette.
5. Click **[OK]**.
   - The Choose Color window closes.
   - The background color updates to your selection on the image view.

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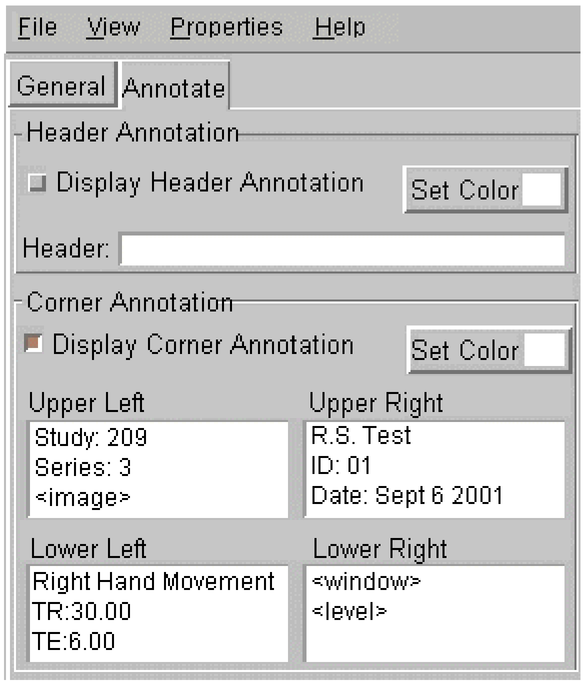
Annotate the Image

Use this procedure to modify the Header and Corner Annotation function by adjusting the text color and annotation views.

1. Select **Properties > View**.
    - The control panel displays the **General** and **Annotate** tabs.
2. Select the **Annotate** tab to move it forward.



3. Select **Display Header Annotation**.
    - The Header Annotation feature is activated.
4. Enter your desired text in the **Header** text box.
    - The annotation displays at the top center of the view.
    - The annotation scales in size based on the length of the text.
5. Click **[Set Color]**.
    - The Choose Color window displays.
6. Select the desired color for text display from the color palette.
7. Click **[OK]**.
    - The Choose Color window closes.
    - The text displays in the Lightbox View and prints, if you have a color printer.

Quick Steps: Control the Image Features Properties

Select a Slice Number

1. Select **Properties > Image Features**.
2. Enter the desired image number in the **Slice Number** text box.

Change the Window and Level Setting

1. Select **Properties > Image Features**.
2. Enter a window setting in the **Window** text box.
3. Enter a level setting in the **Level** text box.
4. Click **[Reset Window/ Level]**, if necessary.
5. Select the desired color scale.

Control the Image Features Properties

The Image Features properties allow you to manually select the slice number of an image to be displayed, window and level setting, mouse, and image color settings. For your ease, the Image Features properties have been separated into these sections:

- Select a Slice Number
- Change the Window and Level Setting
- Select the Mouse Operations
- Adjust the Image Color Settings

Select a Slice Number

Use this procedure to manually select your desired image number in the Lightbox Views.

1. Select **Properties > Image Features**.
   - The Image Feature operations display.
2. Enter the desired image number in the **Slice Number** text box.
   - The image of the slice number you chose displays.
   - Alternatively, you may choose to:
     – Click and drag the Slice Number slider to scroll through the images to make a selection.
     – Press the **Page Up** or **Page Down** keys to scroll through the images.
     – Press and hold the left or right arrow keys on the keyboard to page through the images.

Change the Window and Level Setting

Use this procedure to manually change or reset the image contrast and brightness factors.

1. Select **Properties > Image Features**.
   - The Image Feature operations display.

2. Enter a window setting in the **Window** text box.
   - Window settings control the image contrast.
3. Enter a level setting in the **Level** text box.
   - Level settings controls the image brightness.
4. Click **[Reset Window/Level]**, if necessary.
   - The window and level values restore to the original settings.

Select the Mouse Operations

Use this procedure to select your mouse operation settings for the Lightbox Views.

1. Select **Properties > Image Features**.
   - The Image Feature operations display.
2. Select the mouse action from the **Left** pull-down menu.
   - Pan moves the image in the viewport.
   - W/L alters the window and level settings.
   - Zoom adjusts the image magnification factors.
   - Measure allows distance measurements to be acquired and a measurement report is given in the Message area.
3. Repeat the above step for selecting the mouse operations for the **Middle**, **Right**, **Shift+L** (left), **Shift+M** (middle), and **Shift+R** (right) pull-down menus.

Adjust the Image Color

Use this procedure to make adjustments to the image display color settings in the Lightbox Views.

1. Select **Properties > Image Features**.
   - The Image Feature operations display.
2. Select the desired color scale.
   - Grayscale displays images with varying shades of gray.
     – Scalar values are linearly mapped from black to white.
   - Color displays images with varying shades of color.
     – Scalar values are mapped to a color with values varying linearly.

Quick Steps: Control the Image Features Properties cont.

Select the Mouse Operations

1. Select **Properties > Image Features**.
2. Select the mouse action from the **Left** pull-down menu.
3. Repeat the above step for selecting the mouse actions for the **Middle**, **Right**, **Shift+L** (left), **Shift+M** (middle), and **Shift+R** (right) pull-down menus.

Adjust the Image Color

1. Select **Properties > Image Features**.
2. Select the desired color scale.

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Chapter 10

Paradigm Development

Introduction

NeuroActivator is the paradigm software included in the optional Functional Magnetic Resonance Imaging (fMRI) package. This software is located on your Stimulus personal computer (PC). NeuroActivator allows you to create, preview, and acquire customized paradigms that specifically meet your needs. Paradigms are used when performing brain mapping MRI studies to acquire different types of functional data.

This chapter explains the paradigm customization process. It contains the step-by-step instructions to help you learn how to:

- Start Up the Stimulus PC
- Configure Input and Output Devices
- Configure Feedback and Background Events
- Set Up the Display Properties
- Design a Paradigm
- Save a Paradigm Sequence
- Delete a Paradigm Sequence

In addition, this chapter answers the following questions:

1. What is NeuroActivator?
2. What is a stimulus sequence?
3. What are the available input devices?
4. What are feedback events?
5. What are background events?
6. How do I save a customized paradigm sequence?

What Do I Need to Know About...

This section presents the concepts necessary to successfully create your customized paradigm. Specifically, you need to understand:

- NeuroActivator Description
  - Paradigms
- NeuroActivator Prerequisites
- NeuroActivator Window
  - Sequence Area
  - Group Area
  - Event Area
- Event Behaviors
  - Input/Output Setup Window
  - Feedback Setup Tab
  - Background Setup Tab
  - Display Properties Window
  - Other Properties Window
  - Debug Window
- Saving Your Paradigm

NeuroActivator Description

NeuroActivator is a software tool used for stimulus sequencing and presentation. Currently, it is only used with the BrainWave software, located on your Advantage Windows (AW) workstation. NeuroActivator allows you to present visual and/or auditory stimuli and record responses with timing accuracy. You can configure the software to provide feedback to your patient and record patient responses.

NeuroActivator operates in two modes, clinical (default mode) and research. The clinical mode acquires your paradigm sequences. The research mode allows you to create your own paradigms. The clinical mode must be closed when you want to create a new paradigm.

NOTE: If your system requires a license key, ask your service engineer for the information.

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Paradigms

There are six standard paradigms on the Stimulus PC. Paradigms include task and control time periods. A task is the time period when the responsive stimuli is being presented. The control time period is the time between each task, also known as the rest period. NeuroActivator provides a way to combine the two time periods with graphics, sound, and/or movie clips to create a customized paradigm.

NeuroActivator Prerequisites

Prior to reading this chapter, you should read and understand the Functional Magnetic Resonance Imaging and the Visualize fMRI Data chapters. Both chapters contain necessary information in understanding the importance of paradigms in functional imaging. Paradigms are key instruments for activating specific areas of the brain. Consult a trained physician prior to creating any paradigm. Physicians can help you choose the best stimuli to activate the areas of the brain they are monitoring.

Make sure all sensory equipment is properly connected before beginning an fMRI examination. Sensory equipment is used to deliver the stimulus paradigm and record your patient’s responses.

Gather all of the sensory files needed for your paradigm. These are data files used to create paradigms and can be divided into several types:

- Image
- Reverse CLR (Color)
- Movie
- Animation
- Sound

Each sensory file supports various file extensions, indicating the file type. A file extension is the notation at the end of the file name, preceded by a period. Table 10-1 lists supported file extensions for each sensory file type.

Table 10-1 Sensory File Types

<table>
<tr><th>Sensory Type</th><th>Definition</th><th>Supported File Extension</th></tr>
<tr><td>Image</td><td>Static pictures</td><td rowspan="2">• Bit Map (BMP)
• Graphics Interchange Format (GIF)
• Joint Photographic Experts Group (JPEG)
• Portable Network Graphics (PNG)</td></tr>
<tr><td>Reverse CLR</td><td>Bitmap pictures with reversing color capability</td></tr>
</table>

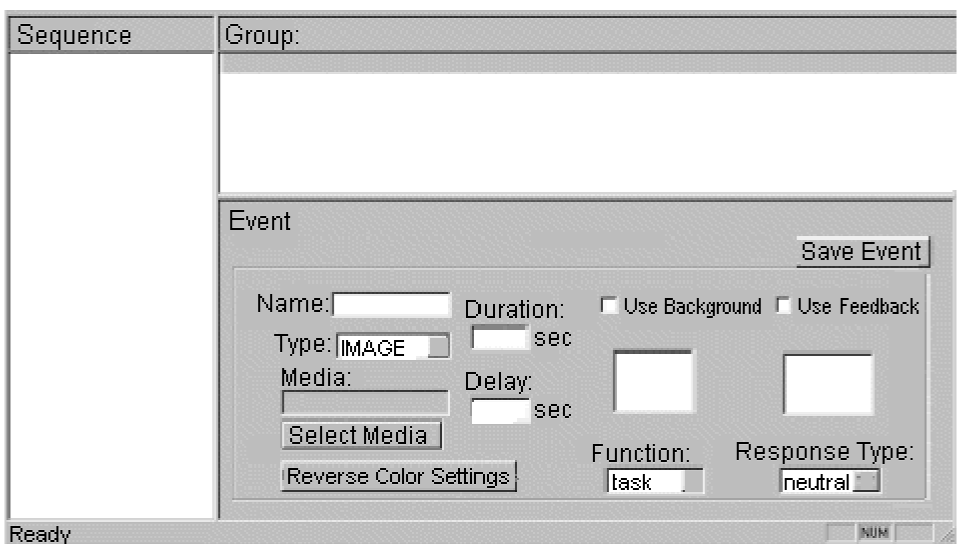
Sensory Type	Definition	Supported File Extension
Movie	Video clip	• Audio Video Interleaved (AVI) • Moving Pictures Group (MPG) • Moving Pictures - Broadcast quality CD-ROM video and audio (MP12) • QuickTime Movie (QT)
Animation	Built-in animation displaying moving dots	
Sound	Audible wave	• Digital Audio Waveforms (WAV)

NeuroActivator Window

The NeuroActivator window (Figure 10-2) is the main window used when creating or modifying paradigms. It is divided into three areas:

- Sequence
- Group
- Event

Figure 10-1 NeuroActivator Window



Sequence Area

The Sequence area allows you to create and modify the structure of a stimulus sequence. Sequences are displayed as a list of events and groups. An event is characterized as a stimulus or delay that lasts for a set time period. A group is characterized as multiple events or multiple groups. However, a group cannot be a combination of both an event and a group.

The events are displayed in numerical order, beginning with one. Adjacent events or groups are separated by a circle icon, called an empty node.

NOTE: The events mentioned above are referred to as standard events. This is to avoid confusion with other events mentioned in this chapter.

Table 10-2 provides a list of the editing options and functions.

Table 10-2 Sequence Area Options

Option	Description
Create	Adds a new standard event or group.
Paste	Adds a previously copied or cut standard event or group.
Copy	Creates a copy of the highlighted standard event or group.
Cut	Removes the highlighted standard event or group.
Delete	Permanently removes the highlighted standard event or group.
Rename	Allows the highlighted standard event or group name to be changed.
Group Properties	Provides the total stimuli acquisition time and order.

Group Area

The Group area displays the events or groups contained in a sequence. The events are listed with the event name and its associated properties. The groups are displayed with three outlining factors:

- Group name
- Total duration time
- Randomization parameter

Event Area

The Event area (Figure 10-2) allows you to customize a standard event. Customizing is only permitted when the standard event is highlighted, either in the Sequence or Group area. Many options presented in this area can also be accessed on various setup windows. Table 10-3 provides a description of the Event options.

Figure 10-2 NeuroActivator Window: Event Area

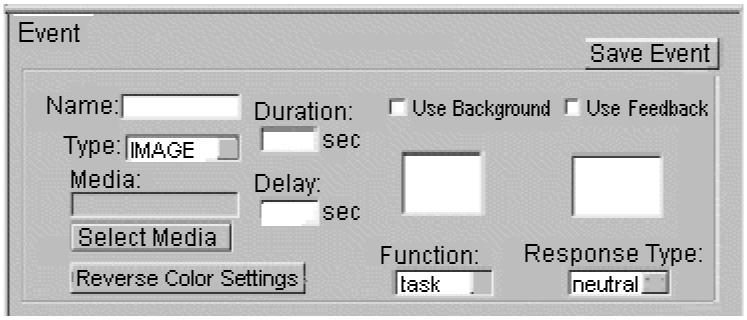


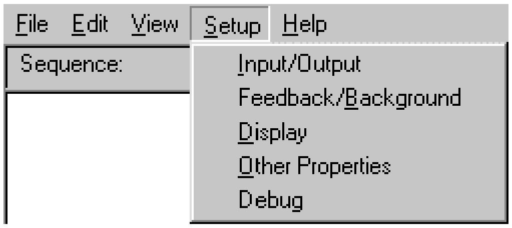
Table 10-3 Event Area Options

Option	Description
Name	Defines the standard event name. The name should not exceed 15 characters.
Type	Provides a list of stimulus types, including image, movie, sound, and visual motion.
Media	Displays the media file name, which is selected with the **[Select Media]** button.
[Select Media]	Opens a selection window that allows you to make your media file selection. The Visual Motion type opens the Animation Setup window.
[Reverse Color Settings]	Switches between the two visual stimuli color settings.
Duration	Displays the time the media performs the event.
Delay	Displays the time interval between each medium, in seconds.
Use Background	Activates a background event and the Background list area. **NOTE:** Refer to the Event Behaviors section of this chapter for additional information.
Background	Displays a list of background events.
Function	Defines the selected event as a task or control action.
Use Feedback	Activates a feedback event and the Feedback list area. **NOTE:** Refer to the Event Behaviors section of this chapter for additional information.
Feedback	Displays the list of response events.
Response Type	Defines what kinds of the response is expected. Response can be positive, negative or neutral.
[Save Event]	Saves the event information.

Event Behaviors

Event behaviors are often referred to as setup parameters. They provide functions for selecting additional Background and Feedback parameters, changing the visual stimuli display settings, and prescribing your animation settings. Event behaviors are defined using the Setup menu options (Figure 10-3) on the Main Menu bar.

Figure 10-3 Setup Menu Options



Selecting an option opens a window containing the parameters available for modification. Each setup window contains the standard functions described in Table 10-4.

Table 10-4 Standard Setup Functions

Function	Description
[OK]	Registers your parameter selections in the NeuroActivator system and closes the current setup window.
[Cancel]	Closes the current setup window without saving any of your parameter selections.
[Help]	Opens the Help window.

Input/Output Setup Window

Your first setup procedure involves prescribing your desired input devices and output options using the Input/Output Setup window (Figure 10-4). The input device options are a mouse, keyboard, or a four button response control. The four button response control provides four options for recording information. Each button can be customized to record the same or different response types.

The information is output to the NeuroActivator software. You can specify an alternative imaging device for triggering the paradigm. If another device is used, it is recommended to test for a signal prior to performing the paradigm, using the **[Pulse Calibration]** button.

Figure 10-4 Input/Output Setup Window

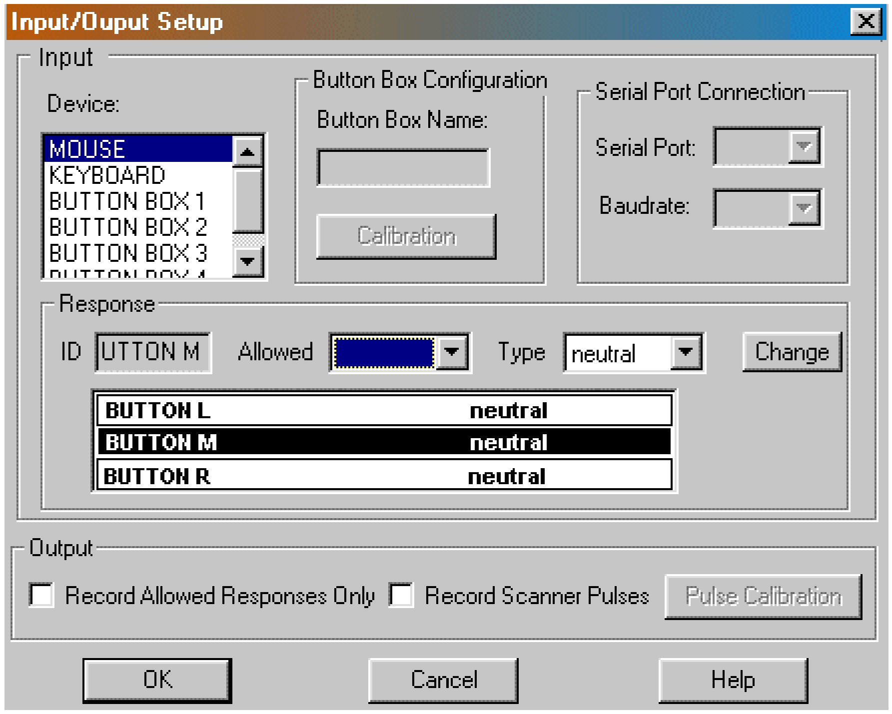


Table 10-5 provides a list of the Input/Output Setup options.

Table 10-5 Input/Output Setup Options

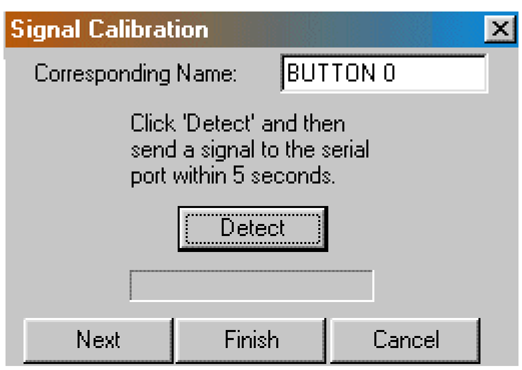
Option	Description
Device	Provides a list of response recording devices, including mouse, keyboard, and button boxes.
Button Box Configuration	
Button Box Name	Displays the hand control name. This area is only activated when a device selection has been made.
[Calibration]	Opens the Signal Calibration window, allowing you to test for response signals generated through the hand controls.
Serial Port Connection	
Serial Port	Provides four Stimulus PC port options. Connection of your response device can be accessed via communication (COM) ports one through four.
Baudrate	Specifies your serial port transfer speed.

Option	Description
Response	
ID (Identification)	Displays the name of the device response key. Once an input device is selected the response area displays the response key types. Selecting a key type automatically updates the **ID** text box.
Allowed	Indicates if the response received is valid. Device calibration is needed prior to making a selection.
Type	Indicates how NeuroActivator interprets a response. Responses can be positive, negative, or neutral. This selection is needed for analyzing response data.
[Change]	Removes all selections made in the Response area.
Output	
Record Allowed Responses Only	Indicates permitted responses only recorded in the event log. If this option is not selected, all responses are recorded.
Record Scanner Pulses	Indicates imaging device pulse signals are being recorded.
[Pulse Calibration]	Opens the Signal Calibration window, which is used to test for incoming signals from an imaging device.

Signal Calibration

Signals received from the hand controls are transferred to the Stimulus PC via a serial port, at a pre-selected speed. A calibration test, enabled with the **[Calibration]** button, is required to ensure the hand controls are working properly (Figure 10-5).

Figure 10-5 Signal Calibration Window



Feedback Setup Tab

A feedback event occurs when a response to a standard event is received. You may program a feedback event to occur with either an allowed or unallowed response. Feedback events can be programed to start if the response is received during a specified time period. When invoked, the feedback event overlaps or temporarily replaces the standard event. For example, if you have prescribed visual stimuli for both the standard and feedback events, the feedback visual replaces the standard visual. After the specified feedback time period has lapsed, the feedback visual is stopped and replaced by the original standard visual.

Another way to use this type of event is during a reaction time window. A reaction time window is defined by two time points, t1 and t2. Each point is measured, in seconds, from the start of a standard event. The t1 time point is entered in the **Shorter Than** text box, displayed in the Reaction Time Window area. The t2 time point is entered in the **Longer Than** text box. If t1 is less than t2, the reaction time window includes reaction times shorter than t1 and longer then t2. If t1 is greater than t2, the reaction time window includes reaction times longer than t2 and shorter than t1. For example, entering 4 seconds in the **Shorter Than** text box and 6 seconds in the **Longer Than** text box, results in the feedback event starting if a detected response is less than 4 seconds or more than 6 seconds. Any time points beyond the total standard event time are excluded from the reaction time windows.

Feedback event parameters are entered in the Background and Feedback Setup window on the **Feedback** tab (Figure 10-6). All feedback event parameters do not have to be prescribed from this tab. Several options can be entered in the Event area. Table 10-6 provides a description of the options not described in the Event area section of this chapter.

NOTE: Refer to Table 10-3 for options not mentioned in the Feedback Options table.

Figure 10-6 Background Feedback Setup Window: Feedback Tab

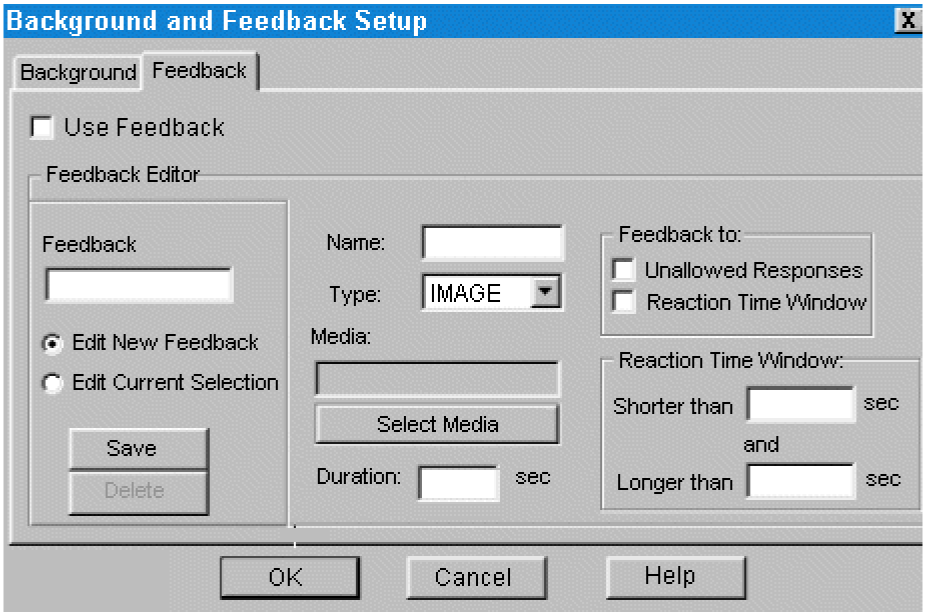


Table 10-6 Feedback Tab Options

Option	Description
Feedback Editor	
Edit New Feedback	Creates a new feedback event.
Edit Current Selection	Modifies an existing feedback event.
[Save]	Saves the edited or new feedback event.
[Delete]	Removes a selected feedback event from the feedback list.
Feedback To	
Unallowed Responses	Initiates a feedback event, if an unallowed response is received.
Reaction Time Window	Initiates a feedback event, if responses are received during the specified reaction time window.
Reaction Time Window	
Shorter Than	Sets a response time limit, measured in seconds. Initiates a feedback event, if a response is received in a time less than the set limit.
Longer Than	Sets a response time limit, measured in seconds. Initiates a feedback event, if a response is received in a time greater than the set limit.

Background Setup Tab

A background event is presented during the rest period of a paradigm. The default event during this time period is a blank screen. Background events can be used to contrast your standard event. For example, if your standard event consisted of several words, the background event could be several arrows or line bars. You can assign more than one background in a group by allocating different background stimuli to the events in the Event area.

The **Background** tab (Figure 10-7) of the Background and Feedback Setup window includes parameter options to create and edit backgrounds. All background parameters do not have to be prescribed from this tab. Several options can be entered in the Event area on the NeuroActivator window. Table 10-7 only explains the options not described in the Event area section of this chapter.

Figure 10-7 Background and Feedback Setup Window: Background Tab

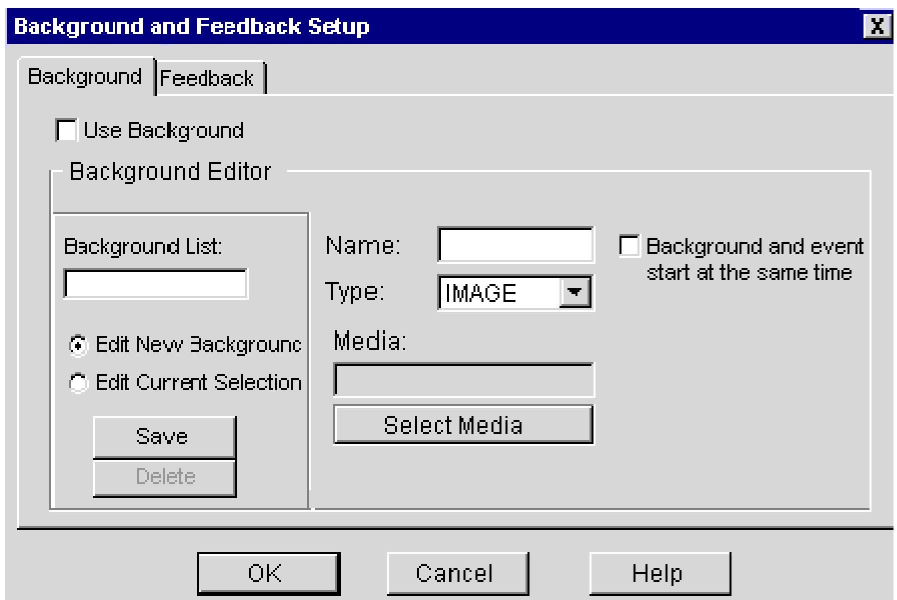


Table 10-7 Background Tab Options

Option	Description
Edit New Background	Allows you to create a new background event.
Edit Current Selection	Allows you to modify an existing background event.
[Save]	Saves the edited or new background selection.
[Delete]	Removes a selected background event from the background list.

Option	Description
Name	Defines the background name. The name should not exceed 15 characters.
Background and Event Start at the Same Time	Initiates an auditory background event to start simultaneously with the standard event. **NOTE:** This option has no affect on visual background events.

NOTE: Refer to Table 10-3 for options not mentioned in the **Background** tab Options table.

Animation Setup

The Animation Setup window is the only setup window that cannot be accessed through the Setup menu options on the Main Menu bar. You can select it in the **Background** tab in the Background and Feedback Setup window or in the Event area of the NeuroActivator window after the Visual Motion media type has been selected. The Animation Setup window (Figure 10-8) allows you to prescribe various animated dot functions. Table 10-8 describes the available options.

Figure 10-8 Animation Setup Window

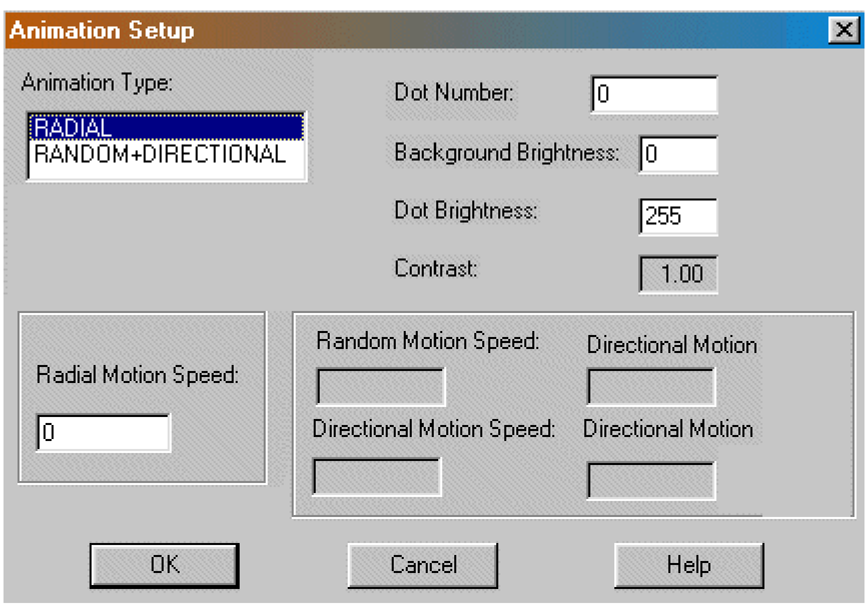


Table 10-8 Animation Setup Window Options

Option	Description
Animation Type	Provides two options for animation dot movement, Radial and Random+Directional.
Dot Number	Indicates the total number of dots displayed. The minimum dot number is 1, the maximum is 400.
Dot Brightness	Provides brightness levels for the dots. Acceptable values range from 0 (white) to 255 (black).
Contrast	Indicates the brightness differences between the foreground and background colors. If the contrast value is positive, the foreground is brighter than the background.
Radial Motion Speed	Indicates the dot speed in pixels per second for radial animations. Acceptable values range from 1 to 400.
Random Motion Speed	Indicates the dot speed in pixels per second for random+directional animations. Acceptable values range from 1 to 400.
Directional Motion Speed	Indicates the number of directions dots can move in pixels per second for random+directional animations. Acceptable values range from 1 to 400.
Directional Motion	Indicates the number of directions the dots can move in for randow+directional animations. Acceptable values range from 1 to 50.

Display Properties Window

Display properties modify the appearance of all visual stimuli in a sequence. Adjustments can be made to the viewing size, mouse cursor effects, and animation display colors. Display properties can be prescribed from the Display Properties window (Figure 10-9) accessed from the Setup menu options on the Main Menu bar. Table 10-9 describes the available options.

Figure 10-9 Display Properties Window

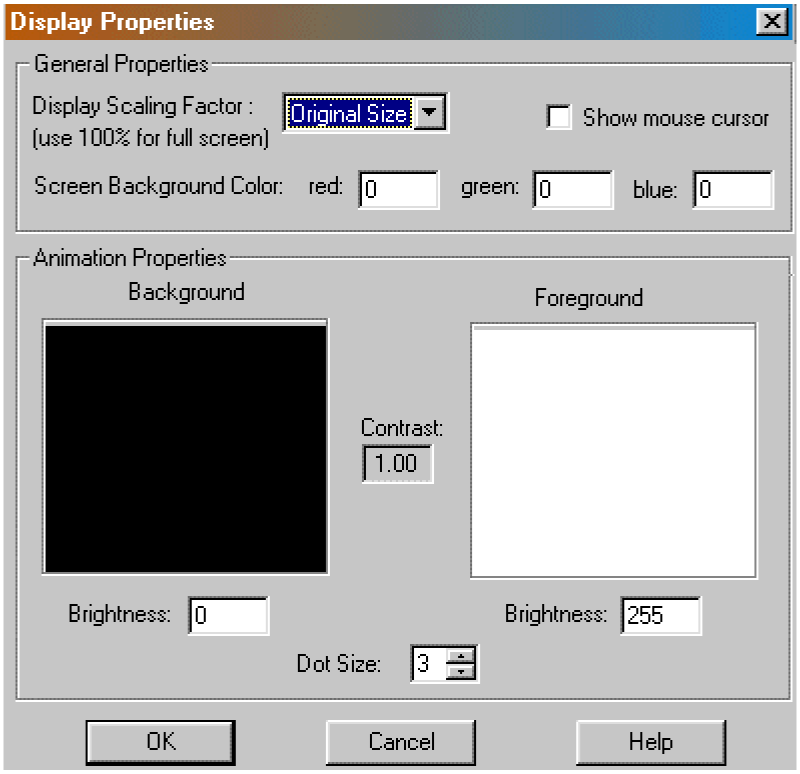


Table 10-9 Display Properties Window Options

Option	Description
	General Properties
Display Scaling Factor	Provides image size display options in percentages of the original image size. Selecting 100% or Original Size for animated dots, displays images on a full screen.
Show Mouse Cursor	Displays the mouse cursor during stimulus presentation.
Screen Background Color	Specifies the background color not filled by the visual event. The background color is a combination of the red, green, and blue spectrum colors. Acceptable values range from 0 to 255.
	Animation Properties
Background	Displays the selected background color.
Foreground	Displays the selected foreground color.
Contrast	Indicates brightness differences between the foreground and background colors. If the contrast value is positive, the foreground is brighter than the background.

Option	Description
Brightness	Allows changes in brightness level for animated events. Acceptable values range from 0 to 255.
Dot Size	Specifies the size of the dots. Each dot displayed in the foreground has a square shape. The size notated is the length of each side of the square, in pixels.

Other Properties Window

The Other Properties window (Figure 10-10) displays miscellaneous paradigm options. All options are presented as features that can be toggled on or off. Checking the desired options activate the features and apply them to the entire sequence. Table 10-10 describes the available options.

Figure 10-10 Other Properties Window

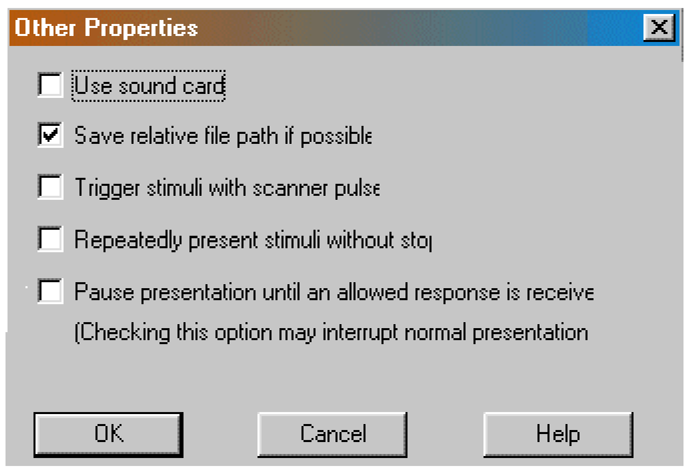


Table 10-10 Other Properties Window Options

Option	Description
Use Sound Card	Activates the sound card feature. Use this option your paradigm includes sound files.
Save Relative File Path If Possible	Records media file names with an .stm extension. Use this feature to save from manually entering the .stm file extension.
Trigger Stimuli With Scanner Pulse	Allows the paradigm to be triggered by a pulse signal, such as a MR system.
Repeatedly Present Stimuli Without Stop	Repeats the entire paradigm sequence until the escape (**ESC**) key is pressed.
Pause Presentation Until an Allowed Response is Received	Operates in a training mode. The program pauses the presentation at a new event, if no allowed responses are received.

Debug Window

The Debug window (Figure 10-11) offers two main functions, it records received responses in a debug format and analyzes your patient logfile with the Response Analyzer. Table 10-11 describes the available options.

Figure 10-11 Debug Window

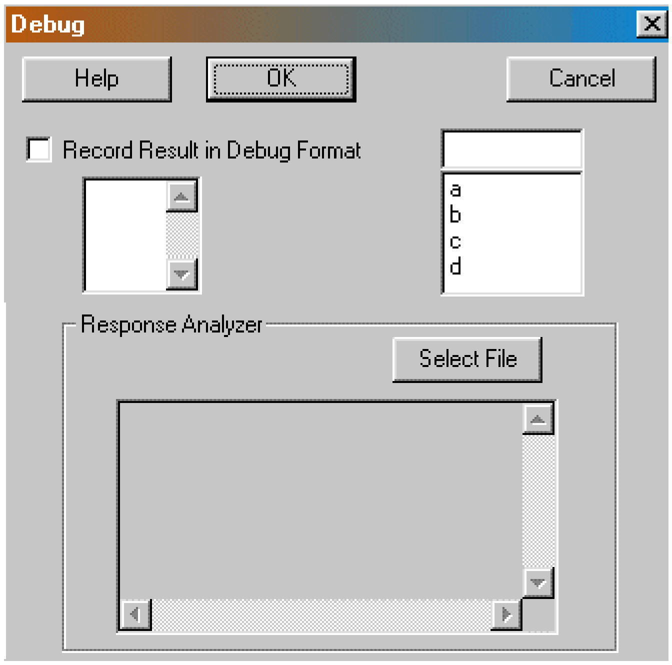


Table 10-11 Debug Window Options

Option	Description
Record Result in Debug Format	Activates the debug recording format. Allows Stimulus PC drive selection of the logfile location.
[Select File]	Opens the Event Logfile Selection window to access and analyze previously saved logfiles.

Saving Your Paradigm

After setting up your paradigm sequence and previewing it, you are ready to save the paradigm. Clicking the **[Save]** button opens the Paradigm Information window (Figure 10-12). This window stores information in the paradigm file required by the BrainWave software. BrainWave uses this information to analyze your fMRI data. Paradigm file names must begin with the letters nn, and end with the file extension .stm. Table 10-12 describes the information required in the Paradigm Information window.

Figure 10-12 Paradigm Information Window

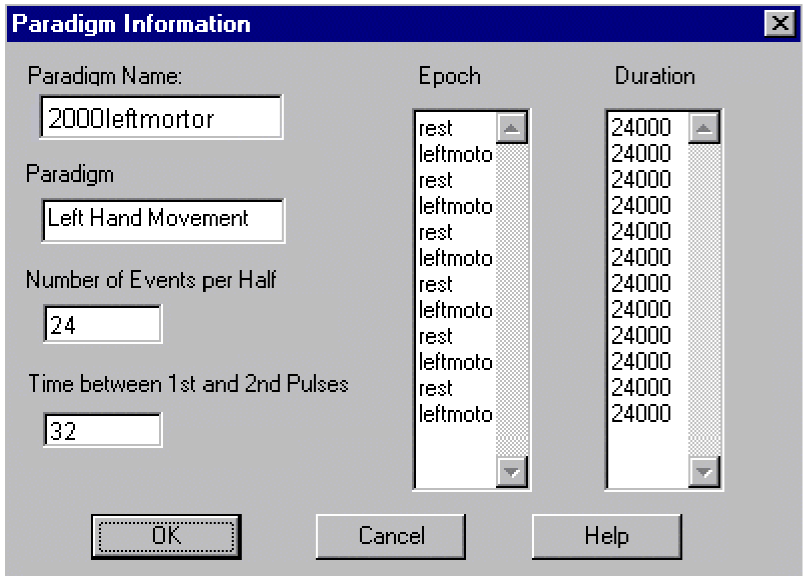


Table 10-12 Paradigm Information Window Options

Option	Description
Paradigm Name	A name for the paradigm should be a single word (no spaces or special characters) preceded by the 2000 series number to ensure easy detection of the name by the BrainWave software. For example, 2000leftmotor. The number and name combination should be different from other saved paradigm names.
Paradigm	A paradigm description used to assign labels to buttons in the BrainWave software.
Number of Events per Half Cycle	The duration of each time period, in seconds, which is termed an Epoch.
Time between 1st and 2nd Pulses	The time, in seconds, between the first pulse and the second pulse. The time can be determined by using the standard trigger pulse time of 8 seconds for the first pulse and the duration of the next time period for the second. For example, if you started your paradigm with a rest period of 8 seconds and the task period is 24 seconds, the time between the pulses would be 32 seconds.
Epoch	An alphanumeric single word (no spaces) description of the events. One event should be labeled rest and the other event, the paradigm name.
Duration	The time, in milliseconds, for each epoch. The total duration time should match the time calculated by the MR system.

How Do I...

This section provides the step-by-step instructions for creating, modifying and running your custom paradigm. Specifically, it describes how to:

- Start Up the Stimulus PC
- Configure Input and Output Devices
  - Set Up the Input Device
  - Set Up the Output Device
- Configure Feedback and Background Events
  - Set Up a Feedback Event
  - Set Up a Background Event
  - Edit or Delete an Event
- Set Up the Display Properties
- Design a Paradigm
  - Set Up the Paradigm
  - Duplicate an Event or Group
  - Preview a Paradigm
- Save a Paradigm Sequence
- Delete a Paradigm Sequence

Start Up the Stimulus PC

Quick Steps: Start Up the Stimulus PC

1. Press the Stimulus PC power button on the Silent Vision box.
2. Press **CTRL + ALT + DELETE**.
3. Enter **`Administrator`** in the **login** text box.
4. Click **[OK]** to close the Login window.
5. Press the space bar or move the mouse to display the Stimulus PC desktop.
6. If desired, switch to the research mode.

The NeuroActivator software can be accessed after starting the Stimulus PC. The clinical version of the NeuroActivator software automatically begins, but you may switch to the research mode if your site has a research agreement.

Use this procedure to start up your Stimulus PC. It also provides the steps to switch your system to research mode.

1. Press the Stimulus PC power button on the Silent Vision box.
   - The Stimulus PC powers on and begins initialization.
2. Press **CTRL + ALT + DELETE**.
   - The Login window opens.
3. Enter **`Administrator`** in the **login** text box.
   - The login name may be automatically entered.
   - A password is not needed.
4. Click **[OK]** to close the Login window.
   - The NeuroActivator message window opens.
   - The system boots up in clinical mode.
5. Press the space bar or move the mouse to display the Stimulus PC desktop.
6. If desired, switch to the research mode.
   a) Right-click the **NeuroActivator** icon.
   b) Select **Exit** to close the clinical version of the software.
   c) Select **Start > Programs > NeuroActivator > NeuroActivator - Research** to enable the research mode.

Configure Input and Output Devices

Set Up the Input Device

Input devices provide a way to identify a response from your patient. Available input devices include a computer mouse, keyboard, or a control box. Use this procedure to set up your input device to allow stimulus recording and triggering.

1. Select **Setup > Input/Output** to open the Input/Output Setup window.
2. Select a **Device** in the Input area.
   - The standard choices are mouse, keyboard, or the button boxes one through four.
   - If you select a button box, the system automatically enters your selection in the **Button Box Name** text box.
3. Select the desired Serial Port Connection, if your input device is a button box.
   a) Select a **Serial Port**.
   b) Select the **Baudrate**.
4. Select the desired **ID** in the Response area.
   - The options are displayed in the lower portion of the Response area.
     – If your input device is a mouse, select L, M, or R.
     – If your input device is a keyboard, select a number 0 to 9 or a letter a through z.
     – If your input device is one of the button boxes, select one of the box numbers once they are calibrated.
   - Your selection is displayed in the **ID** text box.
5. Select the validity of the response in the **Allowed** text box.
   - Yes indicates responses received from the selected ID are valid.
   - No indicates responses received from the selected ID are invalid.
6. Select a response type in the **Type** text box.
   - Neutral indicates all responses.
   - Positive indicates valid responses.
   - Negative indicates invalid responses.

Quick Steps: Set Up the Input Device

1. Select **Setup > Input/Output** to open the Input/Output Setup window.
2. Select a **Device** in the Input area
3. Select the desired Serial Port Connection, if your input device is a button box.
4. Select the desired **ID** in the Response area.
5. Select the validity of the response in the **Allowed** text box.
6. Select a response type in the **Type** text box.

Quick Steps: Set Up the Output Device

1. Select **Setup > Input/Output** to open the Input/Output Setup window.
2. Select the desired output triggering options in the Output area.
3. Click **[Pulse Calibration]** if you have elected to record the scanner pulse.
4. Click **[OK]** to save the input and output information.

Configure Input and Output Devices

Set Up the Output Device

The default output device is the NeuroActivator software. However, you can specify an alternative imaging device for triggering the paradigm.

Use this procedure to configure an alternative output device and ensure you are receiving an incoming signal.

1. Select **Setup > Input/Output** to open the Input/Output Setup window.
2. Select the desired output triggering options in the Output area.
   - Record Allowed Responses Only
   - Record Scanner Pulses
3. Click **[Pulse Calibration]** if you have elected to record the scanner pulse.
   - This is recommended to test for an incoming imaging device signal.
4. Click **[OK]** to save the input and output information.

Configure Feedback and Background Events

Set Up a Feedback Event

A feedback event is triggered by the patient's response. It can be configured to view a response from the selected input device as valid or invalid.

Use this procedure to adjust the parameters in the Background and Feedback Setup window to set up the options for a feedback event.

1. Select **Setup > Feedback/Background** to open the Background and Feedback Setup window.
2. Select the **Feedback** tab to move it forward.
3. Select **Use Feedback**.
    - The Feedback area is activated and lists the previously added feedback events.
    - If no feedback events have been created, the Feedback area appears blank.
4. Select **Edit New Feedback** to activate the create mode.
5. Enter a feedback event name in the **Name** text box.
    - The name must not include symbols, spaces, or more than 15 characters.
6. Select the desired sensory file in the **Type** text box.
    - Refer to Table 10-1 for a description of the types of supported sensory files.
7. Click **[Select Media]**.
8. Select the desired stimuli data file.
    - Refer to Table 10-1 for the supported data file extensions.
9. Click **[Open]**.
    - Your selection is displayed in the **Media** text box.
10. Enter the feedback viewing time in the **Duration** text box.
    - This displays the time the media performs the event, in seconds.

Quick Steps: Set Up a Feedback Event

1. Select **Setup > Feedback/Background** to open the Background and Feedback Setup window.
2. Select the **Feedback** tab to move it forward.
3. Select **Use Feedback**.
4. Select **Edit New Feedback** to activate the create mode.
5. Enter a feedback event name in the **Name** text box.
6. Select the desired sensory file in the **Type** text box.
7. Click **[Select Media]**.
8. Select the desired stimuli data file.
9. Click **[Open]**.
10. Enter the feedback viewing time in the **Duration** text box.
11. Select **Unallowed Responses** (optional).
12. Use the Reaction Time Window option if you want the feedback event to start during a specified time period.
13. Click **[Save]**.
14. Click **[OK]** to close the window.

11. Select **Unallowed Responses** (optional).
    - Only use this option if you want the feedback event to start when an invalid response is given.
12. Use the Reaction Time Window option if you want the feedback event to start during a specified time period.
    a) Select **Reaction Time Window**.
    b) Enter a reaction time, in seconds, in the **Shorter Than** text box.
    c) Enter a reaction time, in seconds, in the **Longer Than** text box.

NOTE: Total time period for steps b and c, should not exceed time allowed for the standard event. Standard even times are the total time it takes to deliver the paradigm sequence.

13. Click **[Save]**.
    - Your feedback event parameters are saved.
    - The background events are listed in the Feedback area.
14. Click **[OK]** to close the window.

Configure Feedback and Background Events

Set Up a Background Event

Background events are stimuli that are present during the rest delay period of a paradigm sequence. These types of events are useful if a contrast to the standard event is needed. You can assign more than one background stimuli to an event.

Use this procedure to set up a background event to present during the rest period of your paradigm.

1. Select **Setup > Feedback/Background** to open the Background and Feedback Setup window.
2. Select the **Background** tab to move it forward.
3. Select **Use Background**.
    - The Background List area is activated and displays the previously created background events.
    - If no background events have been created, the Background List area appears blank.
4. Select **Edit New Background** to activate the create mode.
5. Enter a background event name in the **Name** text box.
    - Your chosen name must not include symbols, spaces, or more than 15 characters.
6. Select the type of sensory file in the **Type** text box.
    - Refer to Table 10-1 for a description of the supported sensory file types.
7. Click **[Select Media]**.
8. Select the desired stimuli data file.
    - Refer to Table 10-1 for the supported data file extensions.
9. Click **[Open]**.
    - Your selection is displayed in the **Media** text box.
10. Select **Background and event start at the same time** (optional).
    - Only use this option if you want to start the standard and background events simultaneously.

Quick Steps: Set Up a Background Event

1. Select **Setup > Feedback/Background** to open the Background and Feedback Setup window.
2. Select the **Background** tab to move it forward.
3. Select **Use Background**.
4. Select **Edit New Background** to activate the create mode.
5. Enter a background event name in the **Name** text box.
6. Select the type of sensory file in the **Type** text box.
7. Click **[Select Media]**.
8. Select the desired stimuli data file.
9. Click **[Open]**.
10. Select **Background and event start at the same time** (optional).
11. Click **[Save]**.
12. Click **[OK]** to close the window.

11. Click **[Save]**.
    - Your background event parameters are saved.
    - The background event is displayed in the Background List area.
12. Click **[OK]** to close the window.

Configure Feedback and Background Events

Edit or Delete an Event

There may be times when you need to modify or remove an existing feedback or background event from the respective display list. Parameter changes to the events are permitted, as well as deletion of an existing event.

Use this procedure to edit or delete an event listed in the Feedback or Background List areas.

1. Select **Setup > Feedback/Background** to open the Background and Feedback Setup window.
2. Select the appropriate event tab.
   - Selecting Feedback moves this tab forward.
   - Selecting Background moves this tab forward.
3. Select **Use Feedback** or **Use Background**.
   - The Feedback or Background List area is activated.
4. Select the event you want to edit.
5. Select **Edit Current Selection**.
   - The edit mode and the delete option become available.
6. Modify the desired parameters or click **[Delete]** if you want to remove the selected event from the list area.
   - Refer to the Event Behaviors section of this chapter for additional parameter information.
7. Click **[Save]** to update the current event.
8. Click **[OK]** to exit.

Quick Steps: Edit or Delete an Event

1. Select **Setup > Feedback/Background** to open the Background and Feedback Setup window.
2. Select the appropriate event tab.
3. Select **Use Feedback** or **Use Background**.
4. Select the event you want to edit.
5. Select **Edit Current Selection**.
6. Modify the desired parameters or click **[Delete]** if you want to remove the selected event from the list area.
7. Click **[Save]** to update the current event.
8. Click **[OK]** to exit.

Set Up the Display Properties

Quick Steps: Set Up the Display Properties

1. Select **Setup > Display** to open the Display Properties window.
2. Select a viewing size in the **Display Scaling Factor** text box.
3. Select **Show mouse cursor** (optional).
4. Adjust the **Screen Background Color** to alter the image background color.
5. Adjust the brightness values in the Animation Properties area.
6. Select a pixel size in the **Dot Size** text box.
7. Click **[OK]** to close the window.

Display properties allow you to make modifications to the appearance of the visual stimuli used in your paradigms. These properties are used to adjust the size of the view, the display of the mouse cursor, background colors, and enter Animation parameters.

Use this procedure to adjust the appearance of the visual stimuli in your paradigm sequence.

1. Select **Setup > Display** to open the Display Properties window.
2. Select a viewing size in the **Display Scaling Factor** text box.
   - The visual stimuli adjust to the selected viewing size.
3. Select **Show mouse cursor** (optional).
   - The mouse cursor is displayed during stimulus presentation.
4. Adjust the **Screen Background Color** to alter the image background color.
   a) Enter a value in the **red** text box.
   b) Enter a value in the **green** text box.
   c) Enter a value in the **blue** text box.
   - Valid color values are 0 to 255.
5. Adjust the brightness values in the Animation Properties area.
   a) Enter a value in the **Brightness** text box for the background.
   b) Enter a value in the **Brightness** text box for the foreground.
   - Valid brightness values are 0 to 255.
6. Select a pixel size in the **Dot Size** text box.
   - Valid sizes range from 0 to 10.
7. Click **[OK]** to close the window.

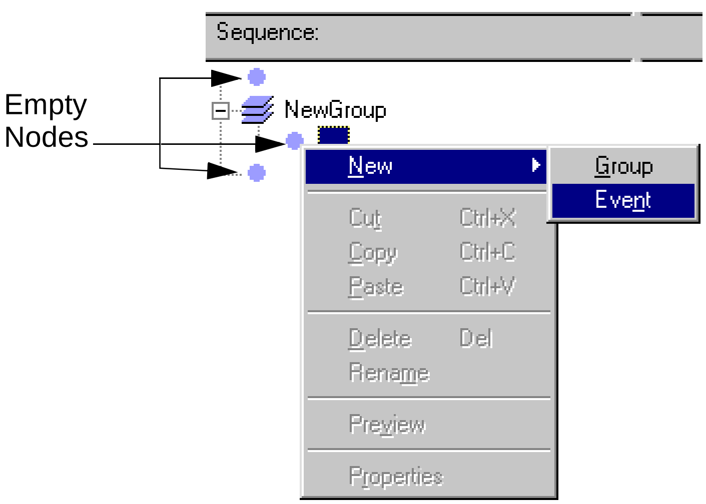
Design a Paradigm

Set Up the Paradigm

A paradigm is a sequence involving at least two repeated events. Events are used as task and rest functions. Paradigm sequences set up with the NeuroActivator software can be used with your MRI system.

Use this procedure to set up a custom paradigm.

1. Click the **NeuroActivator** icon.
   - The NeuroActivator software initializes.
2. Select **File > New > Group**.
   - This creates a group titled NewGroup.
3. Enter a new group name.
   - The name should not exceed 15 characters.
   - Alternatively, you can rename the group using the following steps:
     – Right-click on NewGroup.
     – Select **Rename**.
     – Enter your desired name.
4. Right-click on the empty node.
   - This is positioned under the group name.



Sequence Area

Quick Steps: Set Up the Paradigm

1. Click the **NeuroActivator** icon.
2. Select **File > New > Group**.
3. Enter a new group name.
4. Right-click on the empty node.
5. Select **New > Event**.
6. Enter a new event name.
7. Select the type of sensory file in the **Type** text box.
8. Click **[Select Media]**.
9. Select the desired stimuli data file.
10. Click **[Open]**.
11. Enter a display time in the **Duration** text box.
12. Enter a rest time in the **Delay** text box.
13. Click **[Save Event]** to save the current state of the sequence.

5. Select **New > Event**.
   - This creates a new event.
6. Enter a new event name.
   - The name should not exceed 15 characters.
   - Alternatively, you can rename the event using the following steps:
     - Right-click on NewEvent.
     - Select **Rename**.
     - Enter your desired name.
7. Select the type of sensory file in the **Type** text box.
   - Refer to Table 10-1 for a description of the supported sensory file types.
8. Click **[Select Media]**.
9. Select the desired stimuli data file.
   - Refer to Table 10-1 for the supported data file extensions.
10. Click **[Open]**.
    - Your selection displays in the **Media** text box.
11. Enter a display time in the **Duration** text box.
    - The time is measured in seconds.
12. Enter a rest time in the **Delay** text box.
    - The time is measured in seconds.
13. Click **[Save Event]** to save the current state of the sequence.

Design a Paradigm

Duplicate an Event or Group

Events and groups can be easily duplicated. This is helpful when multiple events occur in the same paradigm.

Use this procedure to quickly copy and paste an event or group to a new location in the paradigm sequence.

1. Right-click on the desired event or group in the Sequence area.
   - This selects the event or group.
   - This also displays a shortcut menu.
2. Select **Copy** to create a copy of the highlighted standard event or group.
3. Right-click on an empty node.
4. Select **Paste** to insert the event or group in this location.
5. Repeat steps 3 and 4 as needed to add additional events or groups.

Quick Steps: Duplicate an Event or Group

1. Right-click on the desired event or group in the Sequence area.
2. Select **Copy** to create a copy of the highlighted standard event or group.
3. Right-click on an empty node.
4. Select **Paste** to insert the event or group in this location.
5. Repeat steps 3 and 4 as needed to add additional events or groups.

Preview a Paradigm

Quick Steps: Preview a Paradigm

1. Right-click on the desired group to preview in the Sequence area.
2. Select **Preview** to display your paradigm sequence.
3. Press the **ESC** key to exit the preview mode.

Preview mode allows you to view your paradigm, prior to saving it. Your paradigm sequence can be viewed at any time during the creation process. After exiting the preview mode, your screen returns you to the place you left in the creation process.

Use this procedure to preview a paradigm while you are in the process of creating it.

1. Right-click on the desired group to preview in the Sequence area.
2. Select **Preview** to display your paradigm sequence.
3. Press the **ESC** key to exit the preview mode.

Save a Paradigm Sequence

After your paradigm has been created, you can save it in the NeuroActivator Research folder.

Use this procedure to save your paradigm sequence.

1. Select **File > Save** to open the Save File window.
2. Enter a paradigm file name.
   - The name must include the letters nn as a prefix and .stm as the file extension.
3. Make sure the Research folder is displayed in the **Save In** text box.
   - If not, follow the path to obtain the folder. C:\Sensor Systems Inc\NeuroActivator 1.0\research.
4. Click **[Save]** to save your paradigm file.
   - The Paradigm Information window opens.
5. Enter a unique name in the **Paradigm Name** text box.
   - A 2000 series number should precede the name you choose. For example, 2000lftmotor.

NOTE: The paradigm 2000 series number and specified name should not be used for any other paradigm name.

6. Enter the remaining paradigm information.
   - Refer to the Saving Your Paradigm section of this chapter for additional information.
   - This information is necessary to analyze your fMRI data.
7. Click **[OK]** to close the window.
8. Select **File > Run**.
   - A message window opens.
9. Click **[OK]** to save the paradigm logfile.
10. Press the **Enter** key to display the paradigm.

Quick Steps: Save a Paradigm Sequence

1. Select **File > Save** to open the Save File window.
2. Enter a paradigm file name.
3. Make sure the Research folder is displayed in the **Save In** text box.
4. Click **[Save]** to save your paradigm file.
5. Enter a unique name in the **Paradigm Name** text box.
6. Enter the remaining paradigm information.
7. Click **[OK]** to close the window.
8. Select **File > Run**.
9. Click **[OK]** to save the paradigm logfile.
10. Press the **Enter** key to display the paradigm.

Delete a Paradigm Sequence

Quick Steps: Delete a Paradigm Sequence

1. Select **File > Open**.
2. Make sure the Research folder is displayed in the **Look In** text box.
3. Select the desired paradigm file to delete.
4. Click **[Open]**.
5. Right-click on the paradigm name.
6. Select **Delete** to remove the paradigm.
7. Click **[Yes]** to confirm the removal the selected files from the system.

You can remove paradigms from the NeuroActivator Research folder. This option is only available when you are in research mode. Refer to the Start Up the Stimulus PC procedure in this chapter for starting the system in research mode.

Use this procedure to remove paradigms that are no longer needed or are invalid.

NOTE: Invalid paradigms are paradigms with duplicating names and/or series numbers.

1. Select **File > Open**.
2. Make sure the Research folder is displayed in the **Look In** text box.
   - If not, follow the path to obtain the folder. C:\Sensor Systems Inc\NeuroActivator 1.0\research.
3. Select the desired paradigm file to delete.
4. Click **[Open]**.
   - Your selected paradigm displays in the Sequence area of the NeuroActivator window.
5. Right-click on the paradigm name.
   - This displays the confirmation window.
6. Select **Delete** to remove the paradigm.
   - Alternatively you could use the following procedure:
     – Click on the paradigm name.
     – Select **Edit > Delete**.
7. Click **[Yes]** to confirm the removal the selected files from the system.

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Chapter 11

2D FIESTA Pulse Sequence

Introduction

The Fast Imaging Employing STeady-state Acquisition (FIESTA) is a fully balanced steady-state coherent imaging pulse sequence designed to produce high signal-to-noise ratio (SNR) images at very short sequence times (TRs).

This chapter explains the pulsing components and timing factors directly related to the 2D FIESTA imaging pulse sequence. It also explains the concepts and the step-by-step instructions to help you learn how to:

- Optimize 2D FIESTA Images
- Prescribe a 2D FIESTA Sequence

In addition, this chapter answers the following questions:

1. What is FIESTA?
2. When would I use a 2D FIESTA pulse sequence?
3. What are the imaging characteristics of a 2D FIESTA pulse sequence?
4. Which imaging options can be used with a 2D FIESTA pulse sequence?
5. What are some applications for the 2D FIESTA sequence?

What Do I Need to Know About...

This section presents the concepts necessary to understand imaging with the 2D FIESTA pulse sequence. Specifically, you need to understand the following concepts:

- 2D FIESTA Basics
- Imaging Effects
- Image Characteristics
- Associated Imaging Options
- Applications

2D FIESTA Basics

The Fast Imaging Employing STeady-state Acquisition (FIESTA) sequence is a fully balanced steady-state coherent imaging pulse sequence designed to produce high SNR images at very short TRs. The pulse sequence uses fully balanced gradients to re-phase the transverse magnetization at the end of each TR interval. For very short TR sequences, the resulting signal intensity is independent of TR and related to (T2/T1). More importantly, the short TRs are essential to maintain spin phase coherence. Phase coherence is required to maintain coherent transverse magnetization and eliminate artifacts generated by magnetic susceptibility induced phase shifts. Thus, the advantages of FIESTA can only be realized with very short TR where (TR << T2) and (TR << 1/b) where b is the local frequency shift caused by inhomogeneity.

NOTE: << indicates “much less than”.

Tissue contrast is generated based on the ratio of the spin-spin relaxation time (T2) and the spin-lattice relaxation time (T1). Hence, the pulse sequence accentuates the contrast of spins with high T2/T1 ratios (such as cerebral-spinal fluid, water, and fat) while suppressing signal from tissues with low T2/T1 ratios (such as muscle and myocardium).

2D FIESTA is a fast-ECG-gated, segmented K-space acquisition. The sequence combines both high temporal resolution with excellent image contrast and can be used for whole body imaging. 2D FIESTA can be used in clinical applications that benefit from the differentiation of contrast between tissues of low T2/T1 ratios (low signal intensity) and high T2/T1 ratios (high signal intensity). This type of acquisition sequence can be useful for imaging structures in motion such as the heart.

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The 2D FIESTA technique uses balanced gradients, which are designed to maintain phase coherence of the transverse magnetization at each radio frequency (RF) excitation. Most other fast scan techniques use phase spoiling to eliminate phase coherence.

Imaging Effects

The sequence parameters have different effects that contribute to the 2D FIESTA images. Table 11-1 summarizes the imaging effects relating to 2D FIESTA and is provided to help you understand the trade-offs that occur when you change the values for a particular parameter.

Table 11-1 Imaging Effects with 2D FIESTA

Parameters	Contrast (T_2/T_s)	Temporal Resolution	Spatial Resolution	SNR	Scan Time	Artifacts
TR ⇓	⇑	⇑	N/A	⇑	⇓	⇓
TE ⇓	⇑	N/A	N/A	⇑	⇓	⇓
Flip Angle ⇑	⇑	N/A	N/A	⇑	N/A	N/A
RBw ⇑	⇑	⇑	N/A	⇓	⇓	⇓
VPS ⇑	N/A	⇑	N/A	N/A	⇓	⇑
Matrix ⇑	N/A	N/A	⇑	⇓	⇑	N/A
Slice Thickness ⇓	N/A	N/A	⇑	⇓	N/A	N/A
FOV ⇓	N/A	N/A	⇑	⇓	N/A	*

NOTE: *There is not always a direct correlation between FOV and artifact. In certain instances, with anatomical size and FOV, some artifact can occur (wrap). In most other circumstances, there will not be a correlation.

Imaging Characteristics

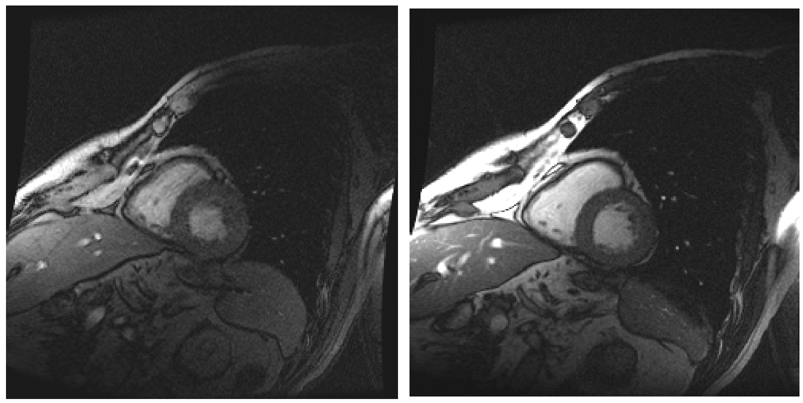
2D FIESTA sequences are capable of producing high signal to noise images with enhanced contrast and temporal resolution. Water and fat contrast is accentuated, while muscle and myocardial tissues are suppressed.

There are several benefits of 2D FIESTA:

- High signal-to-noise images

- Excellent contrast between soft tissues and fluids
- Reduced repetition times, which minimizes motion artifacts
- Inherent flow compensation, which minimizes artifacts due to blood flow

Figure 11-1 Image of 2D FIESTA FastCINE. Note the increased SNR over the standard FastCINE acquisition shown on the left.



FastCINE **2D FIESTA FastCINE**

Table 11-2 Timing differences between the standard FastCINE sequence and the 2D FIESTA FastCINE sequence

Oblique Short Axis FOV = 36 Slice Thickness = 7 mm Matrix = 256x192		**FastCINE**	**2D FIESTA FastCINE**
	TR	7.3 ms	4.0 ms
	TE	2.7 ms	1.8 ms

There are several factors you should consider when using 2D FIESTA:

- The Receive Bandwidth (RBw) is fixed at 125 kHz
- The TE is fixed at the minimum full value
- The smallest FOV with all matrices is 22 cm
- A 512 frequency matrix is not supported by 2D FIESTA

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 11-3, the X's indicate the imaging options available for use with the 2D FIESTA pulse sequence.

Table 11-3 2D FIESTA Pulse Sequence Imaging Options

Imaging Options			
	None	X	Variable Bandwidth
	Flow Compensation	X	No Phase Wrap
	POMP	X	Extended Dynamic Range
X	Square Pixel	X	Image Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer	X	Sequential
X	Cardiac Gating/Triggering		Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi Phase
	Full Echo Train		CCOMP
	ZIP 1024		ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

Applications

2D FIESTA imaging can be used in clinical applications that benefit from the differentiation of contrast between tissues of low T2/T1 ratios (low signal intensity like the myocardium) and high T2/T1 ratios (high signal intensity like blood). This type of acquisition sequence can be useful for imaging, but not limited to, structures in motion such as the heart, which needs clear delineation between the blood and the myocardium. The improved blood pool myocardium contrast allows for better delineation of the myocardial boundaries and hence expedites the determination of the ventricular volumes at end-systole and end-diastole.

WARNING: Ear plugs are required for any person staying inside the scan room during 2D FIESTA scans due to its acoustic noise.

How Do I...

This section provides the step-by-step instructions for prescribing a 2D FIESTA imaging pulse sequence. Specifically, it describes how to:

- Prescribe a 2D FIESTA Sequence

This section also provides the following 2D FIESTA images and an example protocol.

- Cardiac Short or Long Axis

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the "What You Select" column of the matrix uses two other conventions.

- N/A indicates the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

CAUTION: Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.

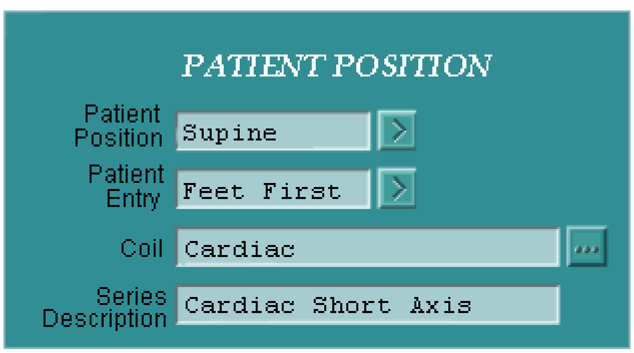
Prescribe a 2D FIESTA Sequence

The 2D FIESTA sequence is useful for imaging structures in motion such as the heart, which needs clear delineation between the blood and the myocardium. The improved blood pool myocardium contrast allows for better delineation of the myocardial boundaries and hence expedites the determination of the ventricular volumes at end-systole and end-diastole.

The decision matrix (Table 11-4) is only for prescribing a 2D FIESTA scan. The following example protocol is for prescribing a short axis cardiac scan for a TwinSpeed™ or an EchoSpeed™ system.

Table 11-4 2D FIESTA Protocol Example (Short Axis Cardiac)

2D FIESTA Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Scan Rx	Acquire a localizer series	Allows Graphic Rx to become available so you can prescribe slices graphically on the localized image.
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol window becomes active.
Patient Position		



Patient Position	**Supine**	Although compatible with any patient position and entry, supine and feet first are recommended. This ensures accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	
Coil	**Phased Array > Cardiac**	Use a coil that produces the optimum coverage and SNR.
Series Description	Enter a series description in the text box.	If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

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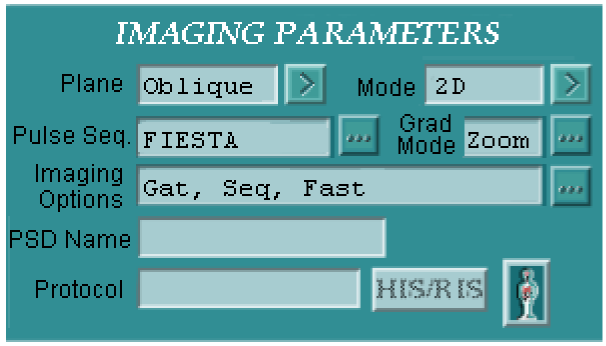
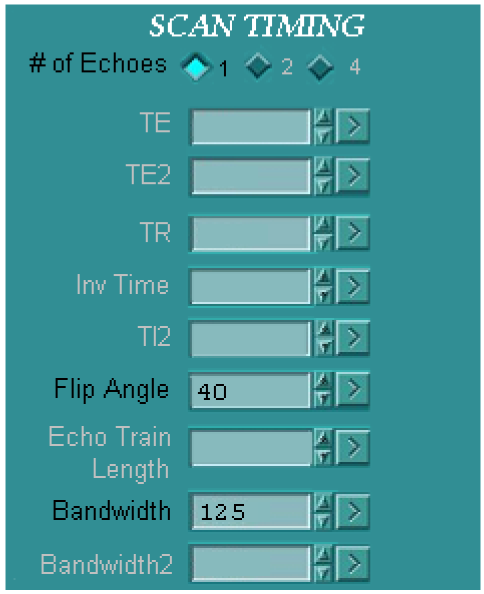
2D FIESTA Protocol Example

What You Select		Selection Notes
Imaging Parameters		



Plane	**Oblique**	Compatible with any scan plane. Select the plane that best meets your clinical need. For cardiac short or long axis imaging, select oblique for proper angle through the heart.
Mode	**2D**	Prescribes a two-dimensional sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Sequence	**FIESTA**	Prescribes a FIESTA pulse sequence.
Imaging Options	**Cardiac Gating Triggering** and **Sequential**	Cardiac Gating/Triggering and Sequential are automatically selected and cannot be turned off. Sequential acquires one slice at a time and multiple cardiac phases.
PSD Name	N/A	
Protocol	N/A	

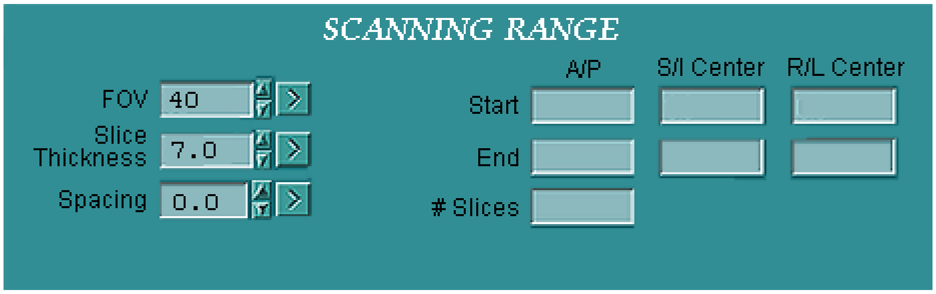
2D FIESTA Protocol Example		
What You Select		Selection Notes
Scan Timing		



# of echoes	N/S	One echo is selected automatically.
TE	N/S	The TE default is minimum full.
TE2	N/A	
TR	N/S	The minimum TR is selected automatically. The calculated TR is the minimum TR attainable and is based on SAR restrictions. The TR may be adjusted through changes to any the following parameters; frequency matrix, FOV, slice thickness and flip angle. You achieve the best image quality at TR of 4 ms or lower.
Inv Time	N/A	
TI2	N/A	
Flip Angle	**40**	The typical flip angle value is 40° to 45°.
Echo Train Length	N/A	
Bandwidth	N/S	The RBw default is 125 kHz.
Bandwidth2	N/A	

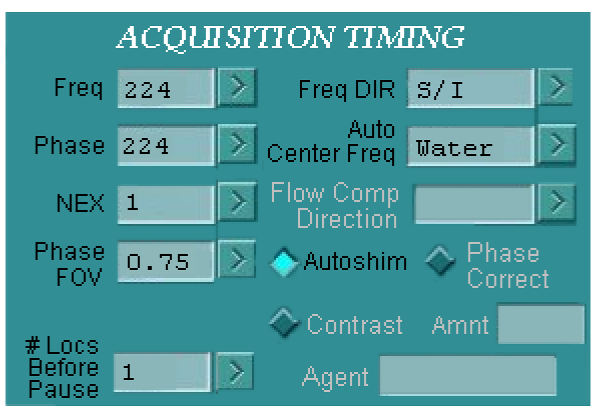
2D FIESTA Protocol Example

What You Select		Selection Notes
Scanning Range		



FOV	**40**	Select a FOV that covers the anatomy of interest, about 40 cm for the chest. Anatomy outside the FOV in the phase direction results in aliasing. Small FOVs produce increased resolution, decreased SNR, and can increase the minimum TE value.
Slice Thickness	**7.0**	The typical slice thickness value for the heart is 7 to 8 mm. Thin slices produce increased resolution and decreased SNR.
Spacing	Enter **`0.0`** in the text box.	Zero spacing is allowed. Slices are acquired sequentially and cross-talk is not a problem.
Start, End Locations		The start and end locations are programmed from the Graphic Rx program after the slices are prescribed.
# Slices		Sequential scan ones slice per acquisition. The number of slices indicates the number of acquisitions prescribed.

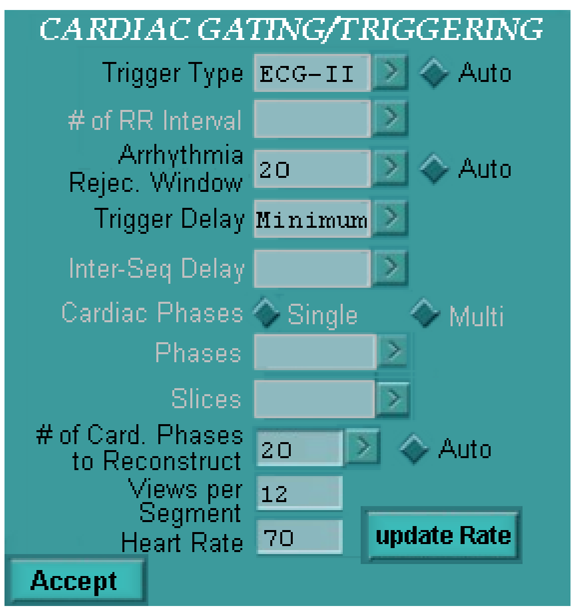
Acquisition Timing



Freq	Enter **`224`** in text box.	Increasing the frequency matrix produces increased resolution, decreased SNR, and decreased number of slices.
Phase	Enter **`224`** in text box.	Phase controls scan time and may control resolution.

2D FIESTA Protocol Example		
What You Select		**Selection Notes**
NEX	**1**	One NEX for sufficient SNR and a reasonable scan time.
Phase FOV	**0.75**	Select a phase FOV to prevent wrapping of anatomy. Choices are 1.0, 0.75, and 0.5. Reducing the phase matrix decreases scan time, FOV in the phase direction, and SNR (slightly).
Freq DIR	**S/I**	The direction displayed is the default frequency direction which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	The CF peak that will be set during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Autoshim can improve image quality and is recommended for this sequence.
Phase Correct	**Off**	Provides no additional benefits and increases prescan time.
# of Locs Before Pause	**1**	After you prescribe the slices, return to this screen and prescribe an automatic pause in the scan at predetermined points for breath-hold studies.

Additional Parameters - Gating/Triggering

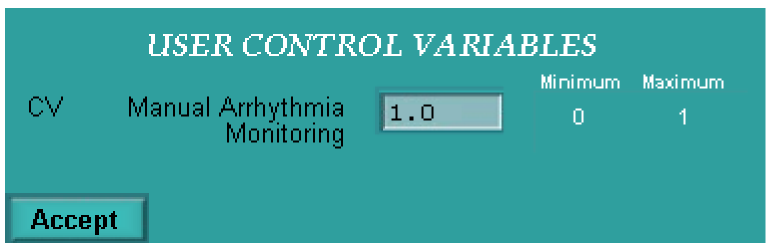


Trigger Type	Select the best lead.	When ECG gating, use the lead that provides the best signal.
# of R-R Interval	N/A	
Arrhythmia Rejec. Window	**20**	Values around 20% are most commonly used to allow a reasonable latitude. If the patient’s heart rate is irregular, increase this value and the TW, then the time available to collect data decreases.

2D FIESTA Protocol Example

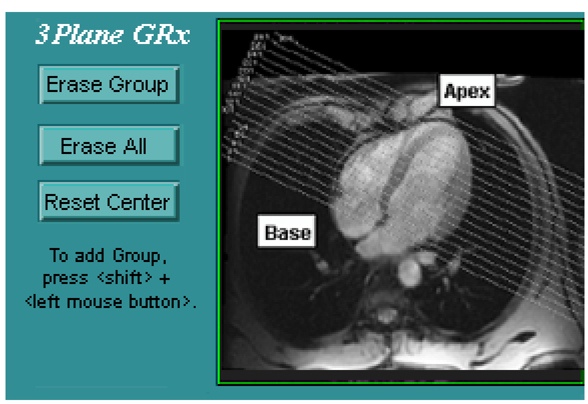
What You Select		Selection Notes
Trigger Delay	**Minimum**	The most minimum TD is desired to cover the full R-R Interval.
Inter-Seq. Delay	N/A	
Cardiac Phases	N/A	
# of Cardiac Phases to Reconstruct	Enter **`20`** in the text box.	Sets the number of cardiac phases to be reconstructed.
Views per Segment	**12**	The typical range of values is 12 to 20 VPS. Heart Rate = 50, select 20 VPS. Heart Rate = 70, select 12 VPS.
Heart Rate	**[update Rate]**	Lets the system obtain an automatic reading of the current heart rate. Updates the rate prior to beginning the scan.
Accept	**[Accept]**	Confirms the selected values and closes Gating/Triggering Additional Parameter screen.

Additional Parameters - User CVs



Manual Arrhythmia Monitoring	**1.0**	Manually monitors arrhythmias. When Auto Arrhythmia Monitoring is on (0), too many triggers are detected outside the TW resulting in an aborted scan.
Accept	**[Accept]**	Confirms selection of User CV and closes the screen.

Additional Parameters - Graphic Rx



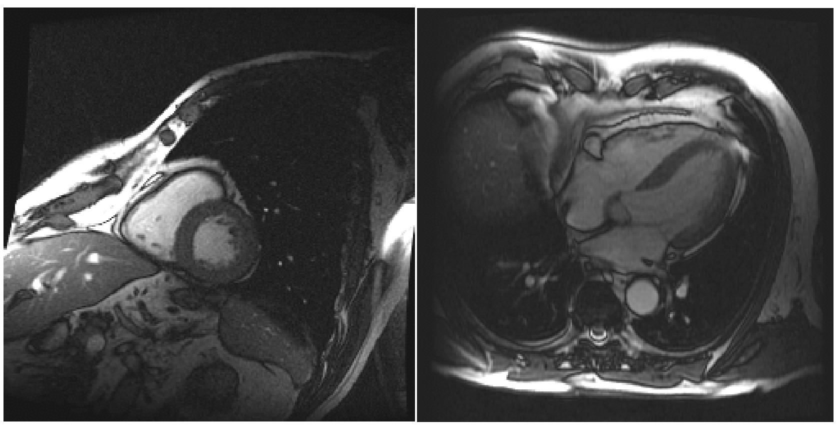
[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.

2D FIESTA Protocol Example		
What You Select		**Selection Notes**
Image Viewport	Click the image to display the line cursor.	Prescribe slices from the cardiac base to the apex for graphic prescription. Select the adjustment handles to angle, draw, and remove slices. Position the slices to cover anatomy of interest and view the Advisory Panel to note the maximum number of slices per acquisition and the number of acquisitions you are prescribing. The scan time increases as the number of acquisitions increase.
Copy Rx	**[Copy Rx]** (optional)	If you had previously graphically prescribed a series with the same plane, FOV, and slice thickness, the prescription can be copied to the exact locations of the prior series.
Erase All	**[Erase All]** (If necessary)	Eliminates the graphic prescription from the screen and allows you to start over.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Accept	**[Accept]**	Confirms the cursor position and closes Graphic Rx.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition. Select for breath-hold acquisitions.
Scan	**[Scan]**	Initiates the acquisition. Instruct the patient to hold his/her breath as long as possible, until the scan stops, if able.

2D Cardiac Short or Long Axis

A Cardiac short or long axis scan can be acquired with a 2D FIESTA pulse sequence to image the heart. This sequence provides improved blood-pool myocardium contrast for better delineation of the myocardial boundaries. Figure 11-2 shows long and short axis images of the heart acquired with 2D FIESTA sequences. Table 11-5 gives you a brief look at an example protocol. The parameters may vary depending on your needs.

Figure 11-2 2D FIESTA Acquisitions



Short Axis **Long Axis**

Table 11-5 2D FIESTA Cardiac Protocol Example

Plane	Mode	Pulse Sequence	PSD Name	TE	TR	Flip Angle	RBw	FOV	Slice Thickness	Slice Spacing
Oblique	2D	FIESTA	N/A	Min Full	N/A	40 to 45	125	~40	7 to 8	0.0

Matrix	NEX	Phase FOV	Frequency Direction	Center Frequency	Auto Shim	Phase Correct	Imaging Options	Sat Pulses
224x224	1	0.75	Unswapped	Water	On	Off	Cardiac Gating/Trig, Sequential	None

Trigger Type	ARW	TD	VPS	Phases	User CVs	Time	Comments
Best Lead	20	Min	12 to 20 HR 50=20 HR 70=12	20	Manual Arrhythmia Monitoring = 1	A function of patients heart rate. Approx 5 to 20 seconds.	Cardiac coil recommended

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Chapter 12

Additional Cardiac Pulse Sequences

Introduction

This chapter explains additional cardiac sequences used in evaluating wall motion abnormalities and pathologic abnormalities within the myocardial tissue. This chapter also explains the concepts of each sequence and provides the step-by-step instructions to help you learn how to:

- Prescribe the Wall Motion Sequence
- Prescribe the Multi Phase FGR-ET Sequence
- Prescribe the IR Prep Gated FGRE Sequence

How Do I...

This section provides the step-by-step instructions for following protocols and prescribing cardiac imaging pulse sequences. Specifically, this section describes how to:

- Prescribe the Wall Motion Sequence
- Prescribe the Multi Phase FGR-ET Sequence
- Prescribe the IR Prep Gated FGRE Sequence

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the “What You Select” column of the matrix uses two other conventions.

- N/A indicates that the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates that the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

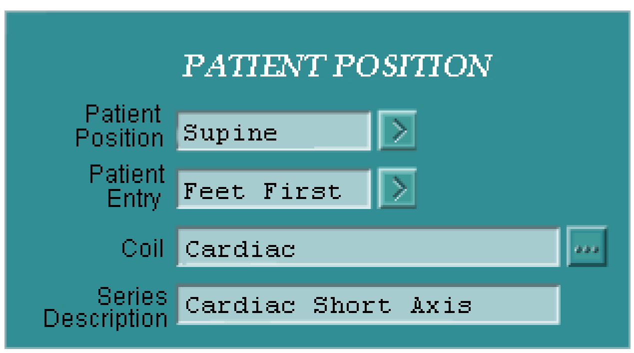
CAUTION: **Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.**

Prescribe the Wall Motion Sequence

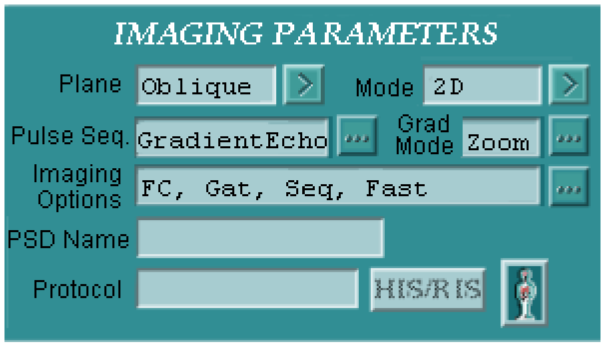
The Wall Motion Sequence is the first series of the three sequence cardiac protocol. It demonstrates functional and anatomical information of the heart. Tagging can be used with this sequence to better visualize contractile function.

The decision matrix (Table 12-1) is only for prescribing a Wall Motion Sequence. The following example protocol is for prescribing a short axis cardiac scan for a TwinSpeed™ or an EchoSpeed™ system.

Table 12-1 Wall Motion Sequence Protocol Example

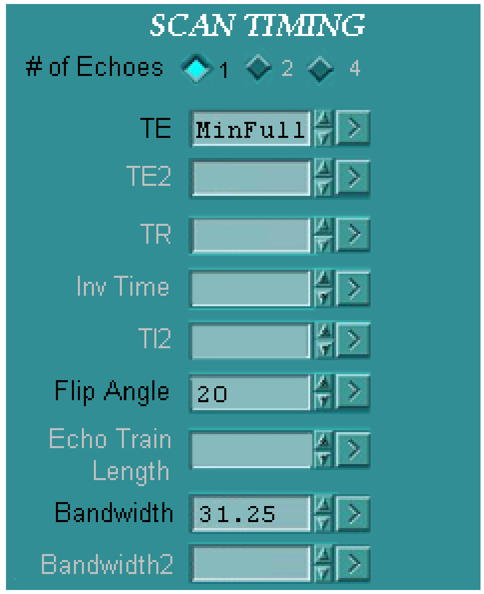
Wall Motion Sequence Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Scan Rx	Acquire a localizer series	Allows Graphic Rx to become available so you can prescribe slices graphically on the localized image.
Rx Manager	**[New Series]**	Adds an additional series to the patient’s exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol window becomes active.
Patient Position		
		
Patient Position	**Supine**	Supine and feet first are recommended to ensure accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	
Coil	**Phased Array > Cardiac**	Use a coil that produces the optimum coverage and SNR.
Series Description	Enter a series description in the text box.	If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

Wall Motion Sequence Protocol Example		
What You Select		Selection Notes
Imaging Parameters		



Plane	**Oblique**	Oblique is used for proper angle through the heart.
Mode	**2D**	Allows prescription of a two-dimensional sequence.
Pulse Sequence	**Fast Card GRE**	Use a FastCard GRE pulse sequence if tagged or a FastCard SPGR if no tags are used.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Imaging Options	**FC**, **Cardiac Gating/ Triggering, and Sequential**	Flow Comp increases signal from blood. Cardiac Gating/Triggering and Sequential are automatically selected. Sequential acquires one slice at a time and multiple cardiac phases. It is required for tagging.
PSD Name	N/A	
Protocol	N/A	

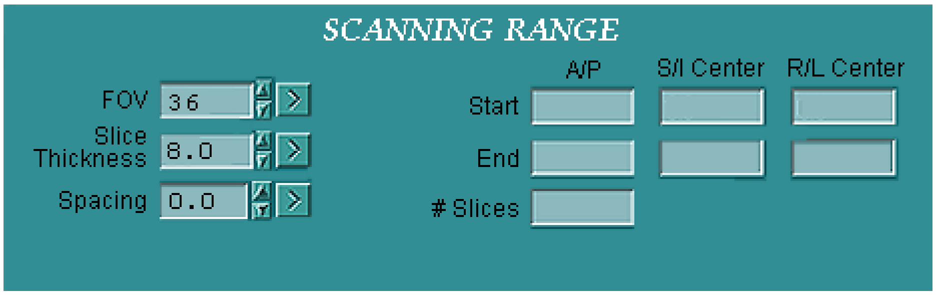
Wall Motion Sequence Protocol Example		
What You Select		**Selection Notes**
Scan Timing		



# of echoes	N/S	One echo is automatically selected.
TE	**Min Full**	Increase TE to produce increased T2* contrast, decreased SNR, and increased magnetic susceptibility artifacts.
TE2	N/A	
TR	N/S	The minimum TR is selected automatically.
Inv. Time	N/A	
TI2	N/A	
Flip Angle	**20**	The typical flip angle value is 20°.
Echo Train Length	N/A	
Bandwidth	**31.25**	The typical Receive Bandwidth value is 31.25 kHz.
Bandwidth2	N/A	

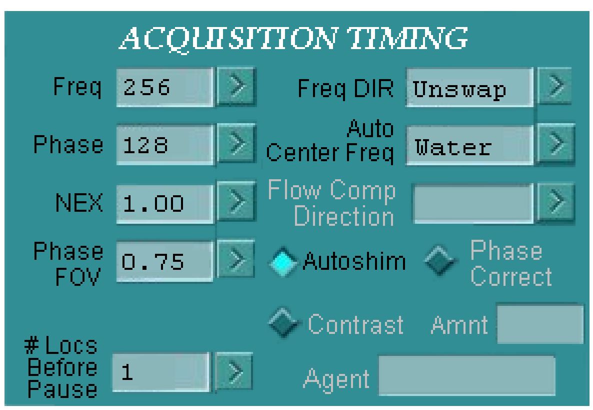
Wall Motion Sequence Protocol Example		
What You Select		**Selection Notes**

Scanning Range



FOV	Enter **36** in the text box.	Select a FOV that covers the anatomy of interest, about 36 cm for the heart. Anatomy outside the FOV in the phase direction results in aliasing. Small FOVs produce increased resolution, decreased SNR, and can increase the minimum TE value.
Slice Thickness	Enter **8** in the text box.	The typical slice thickness value for the heart is 7 to 8 cm. Thin slices produce increased resolution and decreased SNR.
Spacing	Enter **0** in the text box.	Zero spacing is allowed. Slices are acquired sequentially and cross-talk is not a problem.
Start, End Locations		The start and end locations are programmed from the Graphic Rx program after the slices are prescribed.
# Slices		Sequential scans one slice per acquisition. The number of slices indicates the number of acquisitions prescribed.

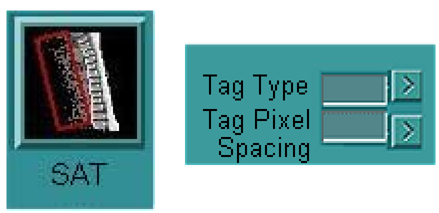
Acquisition Timing



Freq	**256**	Increasing the frequency matrix produces increased resolution and decreased SNR.
Phase	Enter **128** in the text box.	Phase controls scan time and may control resolution.

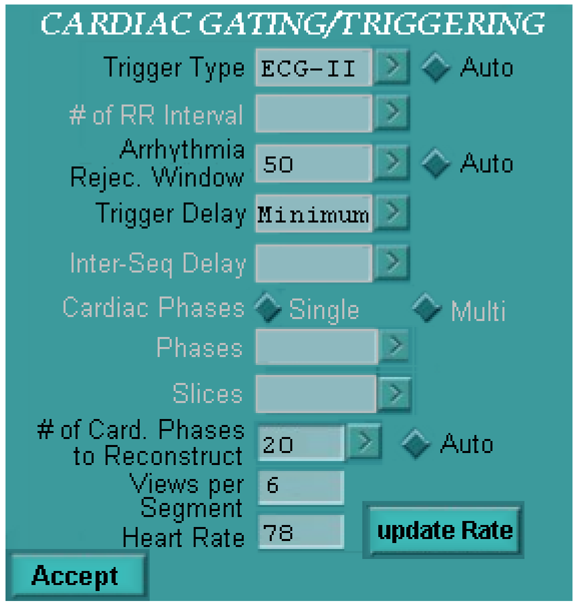
Wall Motion Sequence Protocol Example		
What You Select		**Selection Notes**
NEX	**1**	One NEX for sufficient SNR and a reasonable scan time.
Phase FOV	**0.75**	Select a phase FOV to prevent wrapping of anatomy. Choices are 1.0, 0.75, and 0.5. Reducing the phase matrix decreases scan time, FOV in the phase direction, and SNR (slightly).
Freq DIR	**Unswapped**	The direction displayed is the default frequency direction which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	The CF peak that will be set during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Autoshim can improve image quality and is recommended for this sequence.
Phase Correct	**Off**	Provides no additional benefits for this sequence and increases prescan time.
# of Locs Before Pause	**1**	After you prescribe the slices, return to this screen and prescribe an automatic pause in the scan at predetermined points for breath-hold studies.

Additional Parameters - SAT



Tag Type	**[Stripe]** or **[Grid]**	Sets spatial SAT pulses over anatomy of interest to obtain cardiac images sensitive to tissue motion.
Tag Pixel Spacing	Specify a Pixel separation.	Sets the distance between the tag bands. It is defaulted to a value of 7 pixels and the minimum allowed is 2 pixels. The frequency matrix divided by two (XRES ÷ 2) determines the maximum setting.
Accept	**[Accept]**	Confirms SAT prescription and closes the SAT Rx Additional Parameter screen.

Wall Motion Sequence Protocol Example		
What You Select		**Selection Notes**
Additional Parameters - Gating/Triggering		

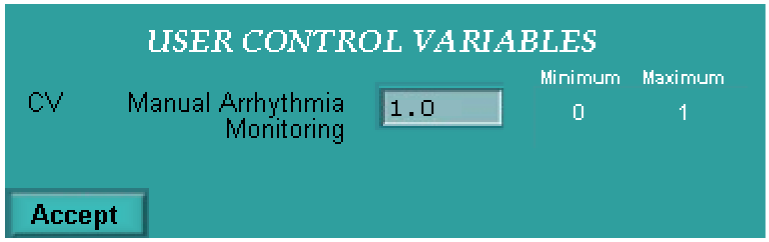


Trigger Type	Select the best lead.	When ECG gating, select the lead that provides the best signal.
# of R-R Interval	N/A	
Arrhythmia Rejection Window	**50**	Values around 50% are most commonly used to allow a reasonable latitude.
Trigger Delay	**Minimum**	The most minimum TD is desired to cover the full R-R Interval.
Inter-Seq Delay	N/A	
Cardiac Phases	N/A	
# of Card. Phases to Reconstruct	**20**	Sets the number of cardiac phases to be reconstructed.
Views per Segment	**6**	The typical value is 1 to 8 VPS. See the VPS Guide for your patient's heart rate.
Heart Rate	**[update Rate]**	Lets the system obtain an automatic reading of the current heart rate. Updates the rate prior to beginning the scan.
Accept	**[Accept]**	Confirms the selected values and closes Gating/Triggering Additional Parameter screen.

Wall Motion Sequence Protocol Example

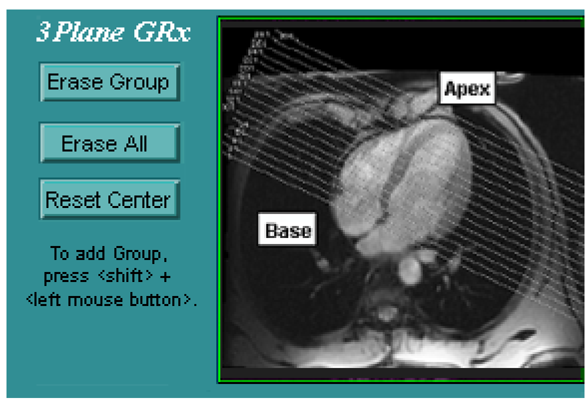
What You Select		Selection Notes

Additional Parameters - User CVs



What You Select		Selection Notes
Manual Arrhythmia Monitoring	**1.0**	Manually monitors arrhythmias. When Auto Arrhythmia Monitoring is on (0), too many triggers are detected outside the TW resulting in an aborted scan.
Accept	**[Accept]**	Confirms selection of User CV and closes the Additional Parameter screen.

Additional Parameters - Graphic Rx



What You Select		Selection Notes
[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.
Image Viewport	Click the image to display the line cursor.	Prescribe the slices from the cardiac base to the apex to display the graphic prescription. Select the adjustment handles to angle, draw, and remove slices. Position the slices to cover anatomy of interest and view the Advisory Panel to note the maximum number of slices per acquisition and the number of acquisitions you are prescribing. The scan time increases as the number of acquisitions increase.
Copy Rx	**[Copy Rx]** (optional)	If you had previously graphically prescribed an oblique series with the same FOV and slice thickness, the prescription can be copied to the exact locations of the prior series.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Erase All	**[Erase All]** (If necessary)	Eliminates the entire graphic prescription from the screen and allows you to start over.

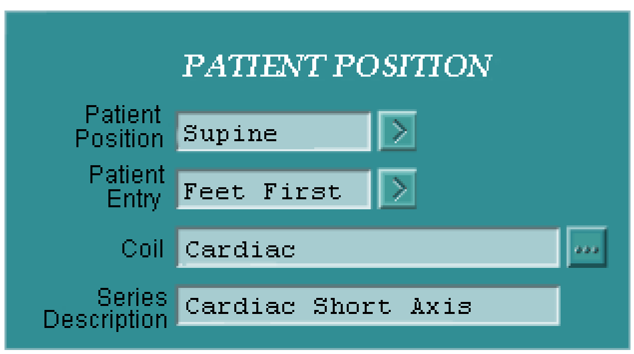
Wall Motion Sequence Protocol Example		
What You Select		**Selection Notes**
Accept	**[Accept]**	Confirms the cursor position and closes the Graphic Rx Additional Parameter screen.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition.
Scan	**[Scan]**	Initiates the acquisition. Instruct the patient to hold his/her breath as long as possible, until the scan stops, if able.

Prescribe the Multi Phase FGR-ET Sequence

The Multi Phase FGR-ET Sequence is the second step in the cardiac protocol. Multiple images are acquired at each slice location over a defined number of cardiac cycles. Each slice location is obtained at the same phase of the cardiac cycle. This sequence also uses IR Prep to suppress the myocardium and enhance T1 contrast so that the tissue is better visualized.

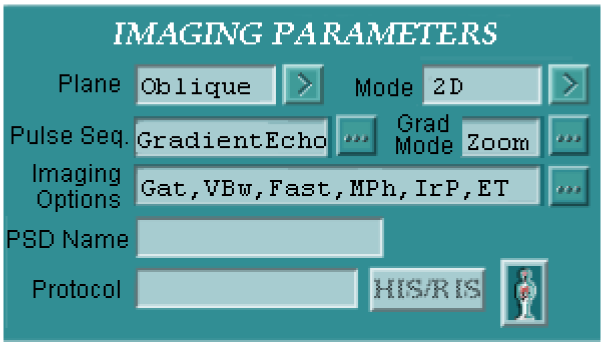
The decision matrix (Table 12-2) is only for prescribing a Multi Phase FGR-ET Sequence. The following example protocol is for prescribing a short axis cardiac scan for a TwinSpeed or an EchoSpeed system.

Table 12-2 Multi Phase FGR-ET Sequence Protocol Example

Multi Phase FGR-ET Sequence Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol window becomes active.
Patient Position		
		
Patient Position	**Supine**	Supine and feet first are recommended to ensure accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	
Coil	**Phased Array > Cardiac**	Use a coil that produces the optimum coverage and SNR.
Series Description	Enter a series description in the text box.	If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

Multi Phase FGR-ET Sequence Protocol Example		
What You Select		**Selection Notes**

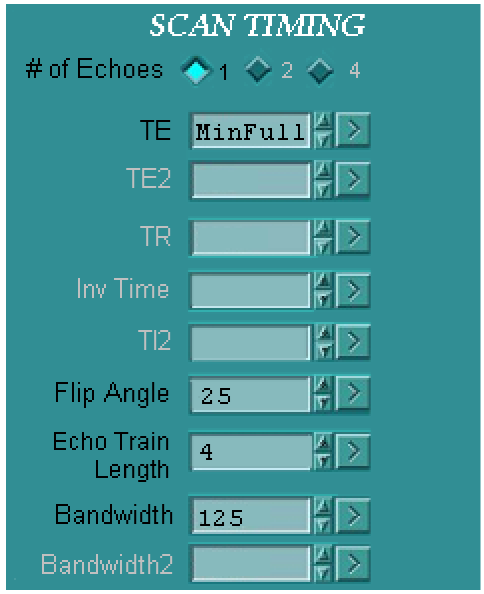
Imaging Parameters



Plane	**Oblique**	Oblique plane is used to obtain the proper angle through the heart.
Mode	**2D**	Allows prescription of a two-dimensional sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Sequence	**Fast GRE ET**	Use a Fast Gradient Echo sequence with echo train readout.
Imaging Options	**Cardiac Gating Triggering**, **Variable Bandwidth**, **Multi Phase**, and **IR Prepared**	Cardiac Gating/Triggering should be selected. Multi Phase is used to acquire multiple images at each slice location. IR Prepared is used to improve T1 contrast.
PSD Name	N/A	
Protocol	N/A	

Multi Phase FGR-ET Sequence Protocol Example

Scan Timing

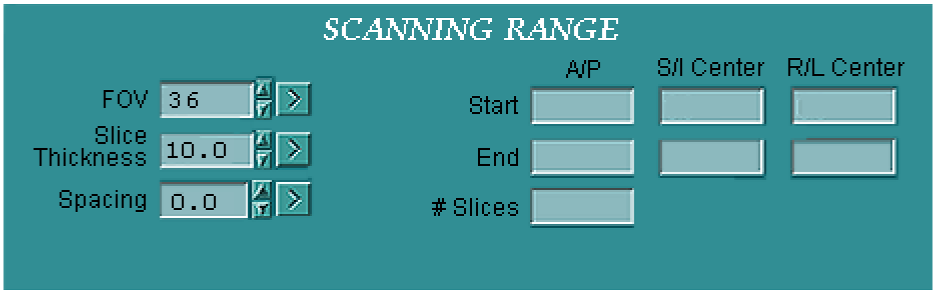


What You Select		Selection Notes
# of echoes	N/S	One echo is automatically selected.
TE	N/S	Only Minimum Full TE is allowed.
TE2	N/A	
TR	N/S	The minimum TR is selected automatically. The minimum TR decreases as RBw increases, and as ETL, frequency matrix, and obliquity decrease.
Inv. Time	N/S	The Inversion Time is automatically calculated based on the other sequence parameters. The TI is generally in the range of 150 to 175 ms when 0.75 PFOV is selected. Otherwise, the TI is >230 ms, causing poor fat suppression.
TI2	N/A	
Flip Angle	Enter **25** in the text box.	The typical flip angle value is 25°.
Echo Train Length	**4**	As the ETL is increased, TR increases, and image blurring increases. Note the (phase matrix x PFOV) must be an even multiple of the ETL. The system posts a message if this is not followed.
Bandwidth	**125**	The typical RBw value is 125 kHz. Generally, wider bandwidths are used to minimize TR and TE values.
Bandwidth2	N/A	

Multi Phase FGR-ET Sequence Protocol Example

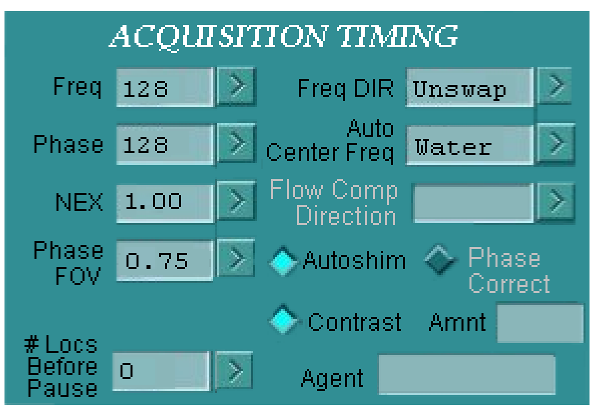
What You Select		Selection Notes

Scanning Range



FOV	Enter **36** in the text box.	Select a FOV that covers the anatomy of interest, about 32 to 40 cm. Anatomy outside the FOV in the phase direction results in aliasing. Small FOVs produce increased resolution, decreased SNR, and can increase the minimum TE value.
Slice Thickness	**10**	10 mm is generally used to obtain coverage through the entire heart on this sequence.
Spacing	Enter **0** in the text box.	Zero spacing for complete coverage.
Start, End Locations		The start and end locations are programmed from the Graphic Rx program after the slices are prescribed.
# Slices		The maximum number of slices per acquisition depends on the heart rate, the number of R-R Intervals, the ETL, TR, and frequency matrix.

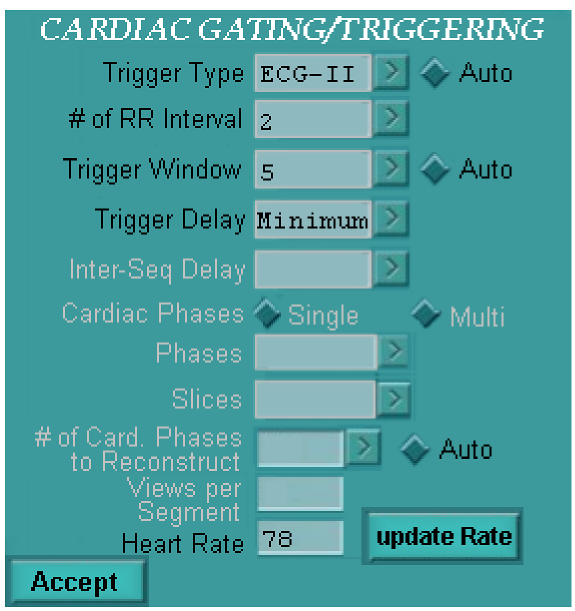
Acquisition Timing



Freq	**128**	Increasing the frequency matrix decreases echo space, SNR, the number of slice locations allowed, while increasing resolution. Available selections are 64 to 256, in steps of 32.
Phase	**128**	Phase controls scan time and resolution. The phase matrix cannot exceed the frequency matrix. Available selections are 64 to 256, in steps of 32. Note the (phase matrix x PFOV) must be an even multiple of the ETL.

Multi Phase FGR-ET Sequence Protocol Example		
What You Select		**Selection Notes**
NEX	N/S	One NEX is used automatically.
Phase FOV	**0.75**	Select a PFOV of 1.0 to prevent wrapping of anatomy. Choices are 1.0, 0.75, and 0.5. Reduce the phase matrix to decrease scan time, FOV in the phase direction, and SNR (slightly). The (phase matrix x PFOV) must be an even multiple of the ETL. Due to effects on TI, 0.75 PFOV is recommended.
Freq DIR	**Unswapped**	The direction displayed is the default frequency direction which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	The CF peak that will be set during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Autoshim can improve image quality and is recommended.
Phase Correct	**Off**	Provides no additional benefits and increases prescan time.
# of Locs Before Pause	**0**	This sequence should not be segmented in relation to time and therefore should not have a pause. The scan time is approximately 40 seconds or more and is performed as a breath hold for as long as possible. Locations before pause should be zero.

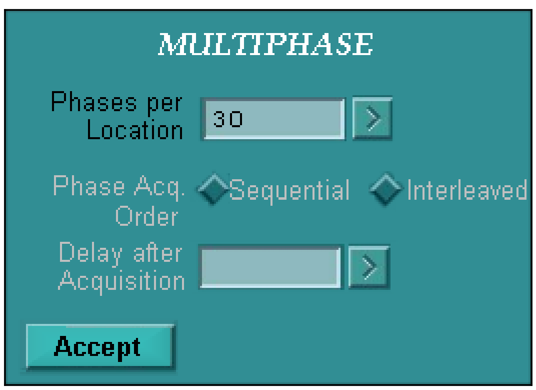
Additional Parameters - Gating/Triggering



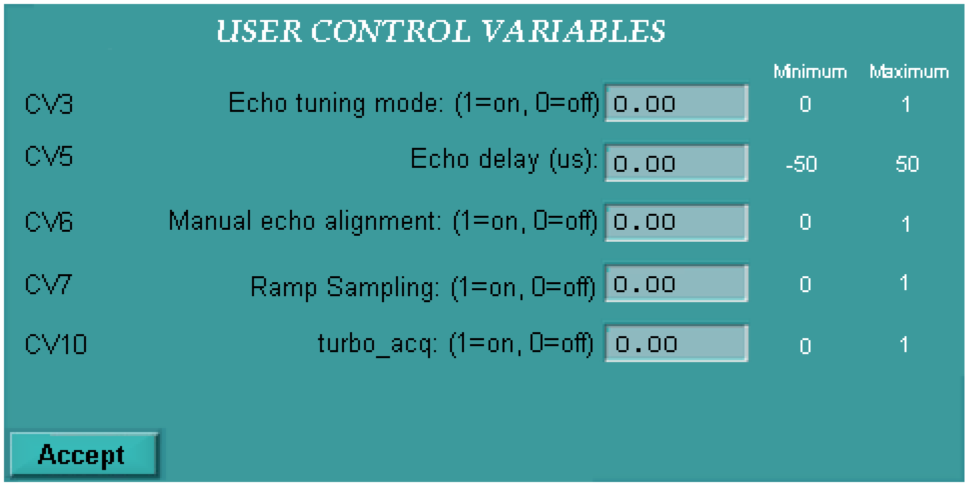
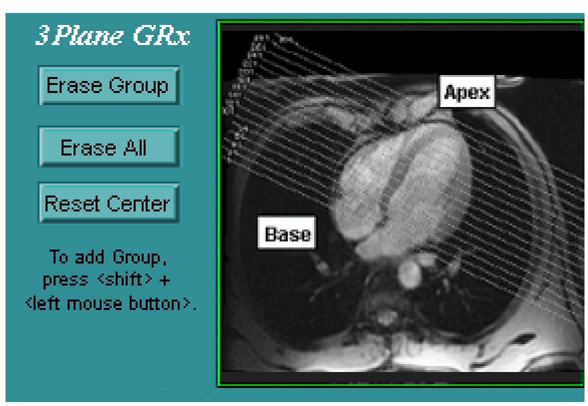
Trigger Type	Select the best lead.	When ECG gating, select the lead that provides the best signal.
# of R-R Interval	**2**	1, 2, 3, or 4 x R-R Interval is available. As the heart rate increases, a larger R-R Interval is needed for complete coverage of the heart.

Multi Phase FGR-ET Sequence Protocol Example		
What You Select		**Selection Notes**
Trigger Window	**5**	Values of 5 to 10 are most commonly used. As the TW increases, the number of slice locations allowed decreases. Use larger values on patients with irregular heart rates. Actual scan times are longer than expected if triggers are detected outside the TW.
Trigger Delay	**Minimum**	The most minimum TD is desired to cover the full R-R Interval.
Inter-Seq Delay	N/A	
Cardiac Phases	N/A	
# of Card. Phases to Reconstruct	N/A	
Views per Segment	N/A	
Heart Rate	**[update Rate]**	Lets the system obtain an automatic reading of the current heart rate. Updates the rate prior to beginning the scan.
Accept	**[Accept]**	Confirms the selected values and closes Gating/Triggering Additional Parameter screen.

Additional Parameters - Multi Phase



Phases per Location	Enter **30** in the text box.	Defines the number of times the sequence repeats, and therefore, the number of images acquired for each slice location. Typically 30 to 45 phases.
Phase Acq. Order	N/A	
Delay after Acquisition	N/A	
Accept	**[Accept]**	Confirms the selected value and closes Multi Phase Additional Parameter screen.

Multi Phase FGR-ET Sequence Protocol Example		
What You Select		**Selection Notes**
Additional Parameters - User CVs		
		
Echo tuning mode	**0.00**	All User CVs for this sequence are turned off (0=off). Refer to the **What Do I Need to Know About...** section for the discussion on Manual Echo Alignment.
Echo delay	**0.00**	
Manual echo alignment	**0.00**	
Ramp Sampling	**0.00**	
turbo_acq	**0.00**	
Accept	**[Accept]**	Confirms the selected values and closes User CVs Additional Parameter screen.
Additional Parameters - Graphic Rx		
		
[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.

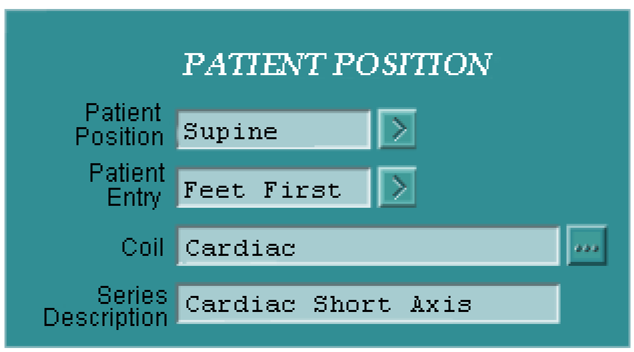
Multi Phase FGR-ET Sequence Protocol Example		
What You Select		**Selection Notes**
Image Viewport	Click the image to display the line cursor.	Prescribe the slices from the cardiac apex to the base to display the graphic prescription. Select the adjustment handles to angle, draw, and remove slices. Position the slices to cover anatomy of interest and view the Advisory Panel to note the maximum number of slices per acquisition and the number of acquisitions you are prescribing.
Copy Rx	**[Copy Rx]** (optional)	If you had previously graphically prescribed an oblique series with the same FOV and slice thickness, the prescription can be copied to the exact locations of the prior series.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Erase All	**[Erase All]** (If necessary)	Eliminates the graphic prescription from the screen and allows you to start over.
Accept	**[Accept]**	Confirms the cursor position and closes the Graphic Rx Additional Parameter screen.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition.
Scan	**[Scan]**	Initiates the acquisition. Instruct the patient to hold his/her breath as long as possible, until the scan stops, if able.

Prescribe the IR Prep Gated FGRE Sequence

The IR Prep Gated FGRE Sequence is the last of three pulse sequences in the cardiac protocol to evaluate the LV myocardium.

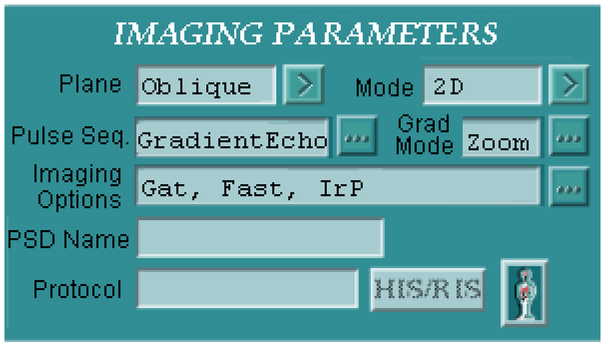
The decision matrix (Table 12-3) is only for prescribing an IR Prep Gated FGRE Sequence. The following example protocol is for prescribing a short axis cardiac scan for a TwinSpeed or an EchoSpeed system.

Table 12-3 IR Prep Gated FGRE Sequence Protocol Example

IR Prep Gated FGRE Sequence Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Rx Manager	**[New Series]**	Adds an additional series to the patient’s exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol window becomes active.
Patient Position		
		
Patient Position	**Supine**	Supine and feet first are recommended to ensure accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	
Coil	**Phased Array > Cardiac**	Use a coil that produces the optimum coverage and SNR.
Series Description	Enter a series description in the text box.	If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

IR Prep Gated FGRE Sequence Protocol Example

What You Select		Selection Notes
Imaging Parameters		

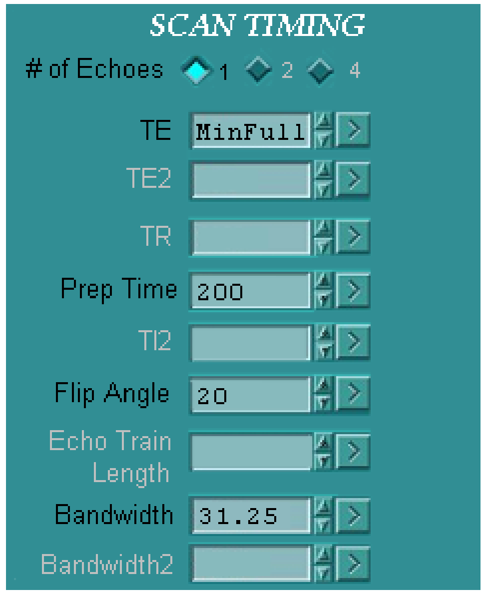


Plane	**Oblique**	Oblique is used for proper angle through the heart.
Mode	**2D**	Allows prescription of a two-dimensional sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Sequence	**Fast GRE**	Use a Fast GRE pulse sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Imaging Options	**Cardiac Gating Triggering** and **IR Prepared**	Cardiac Gating/Triggering should be selected. IR Prepared is used to improve T1 contrast.
PSD Name	N/A	
Protocol	N/A	

IR Prep Gated FGRE Sequence Protocol Example

What You Select		Selection Notes

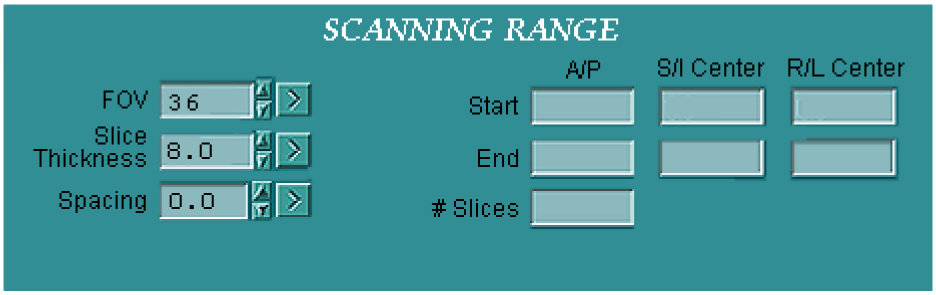
Scan Timing



# of echoes	N/S	One echo is automatically selected.
TE	**Min Full**	Increase TE to produce increased T2* contrast, decreased SNR, and increased magnetic susceptibility artifacts.
TR	N/S	The minimum TR is selected automatically.
Prep Time	**200**	The typical TI value with IR Prepared and 1 R-R selected is 200. The typical TI value with 2 R-R is 325. This can change from patient to patient.
TI2	N/A	
Flip Angle	**20**	The typical flip angle value is 20°.
Echo Train Length	N/A	
Bandwidth	**31.25**	The typical RBw value is 31.25 kHz.
Bandwidth2	N/A	

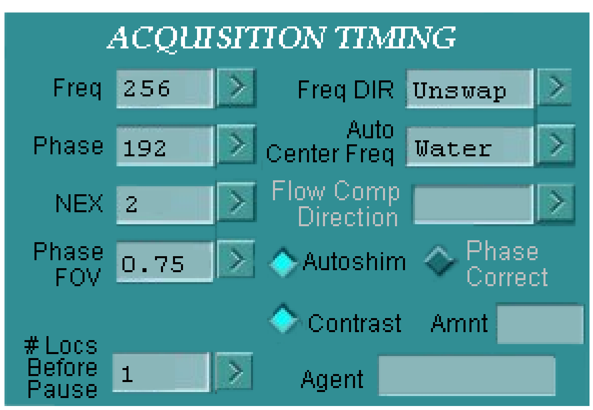
IR Prep Gated FGRE Sequence Protocol Example		
What You Select		**Selection Notes**

Scanning Range



FOV	Enter **36** in the text box.	Select a FOV that covers the anatomy of interest, about 36 cm for the heart. Anatomy outside the FOV in the phase direction results in aliasing. Small FOVs produce increased resolution, decreased SNR, and can increase the minimum TE value.
Slice Thickness	Enter **8.0** in the text box.	The typical slice thickness value for the heart is 7 to 8 cm. Thin slices produce increased resolution and decreased SNR.
Spacing	Enter **0.0** in the text box.	Zero spacing for complete coverage.
Start, End Locations		The start and end locations are programmed from the Graphic Rx program after the slices are prescribed.
# Slices		Use the minimum number of locations needed to cover the entire heart. The R-R Interval and TW affect the number of slices per acquisition. As the heart rate increases, the slices per acquisition decreases. Increase the TW and the slices per acquisition decreases. The number of acquisitions is shown on the Advisory panel.

Acquisition Timing

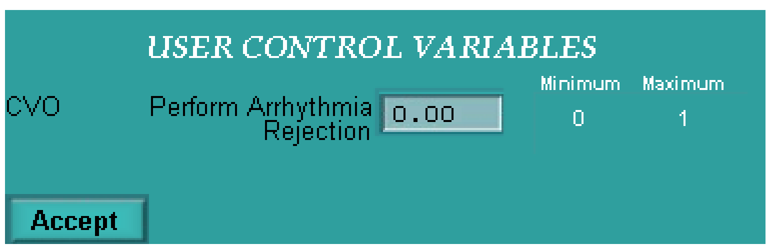


Freq	**256**	Increasing the frequency matrix produces increased resolution and decreased SNR.

IR Prep Gated FGRE Sequence Protocol Example

What You Select		Selection Notes
Phase	**192**	Phase controls scan time and may control resolution.
NEX	**2**	Two NEX for sufficient SNR and a reasonable scan time.
Phase FOV	**0.75**	Choices are 1.0, 0.75, and 0.5. Reduce the phase matrix and thus decrease scan time, FOV in the phase direction, and SNR (slightly).
Freq DIR	**Unswapped**	The direction displayed is the default frequency direction which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	The CF peak that will be set during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Autoshim can improve image quality and is recommended.
Phase Correct	**Off**	Provides no additional benefit for this sequence and increases prescan time.
# of Locs Before Pause	**1**	Prescribes an automatic pause in the scan at predetermined points for breath-hold studies. You can only acquire one slice per breath hold for this sequence.

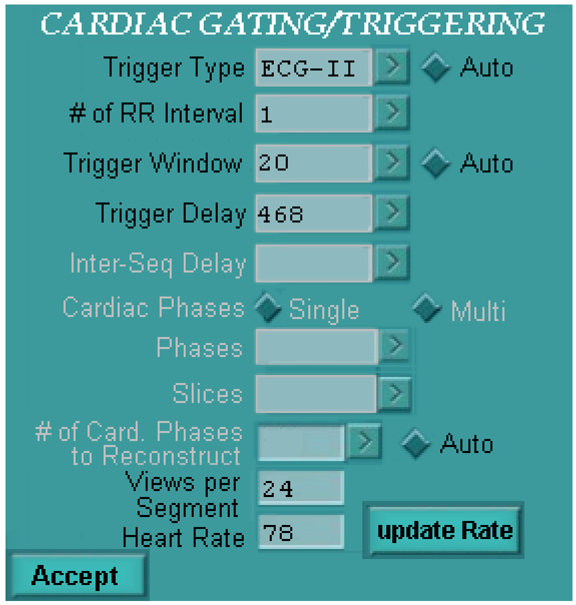
Additional Parameters - User CVs



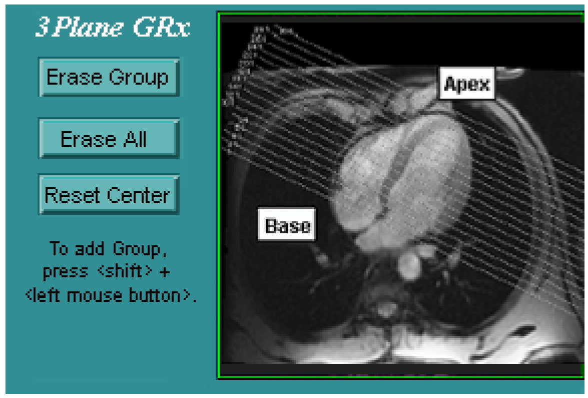
Perform Arrhythmia Rejection	**0.00**	Using Arrhythmia Rejection (1) results in an increase in scan time if triggers occur prior to the TW, but image quality will improve. Too many triggers detected outside the TW results in an aborted scan.
Accept	**[Accept]**	Confirms selection of User CV and closes the Additional Parameter screen.

IR Prep Gated FGRE Sequence Protocol Example

What You Select		Selection Notes
Additional Parameters - Gating/Triggering		



Trigger Type	Select the best lead.	When ECG gating, select the lead that provides the best signal.
# of R-R Interval	**1**	1 or 2 x R-R Intervals are available to change your image contrast.
Trigger Window	**20**	The typical value for TW for this sequence is 20.
Trigger Delay	Enter value of 60% of the R-R Interval value.	Note the patient's R-R Interval, calculate 60% of the value, and input the new value for the TD. For example, if your patient's R-R Interval is 780, then 60% x 780 = 468. You would then type in 468 in the TD text box.
Inter-Seq. Delay	N/A	
Cardiac Phases	N/A	
# of Card. Phases to Reconstruct	N/A	
Views per Segment	**24**	To collect the images faster, since the sequence acquires one slice per breath hold, typical values are 24 to 32 VPS.
Heart Rate	**[update Rate]**	Lets the system obtain an automatic reading of the current heart rate. Update the rate prior to beginning the scan.
Accept	**[Accept]**	Confirms the selected values and closes the Gating/Triggering Additional Parameter screen.

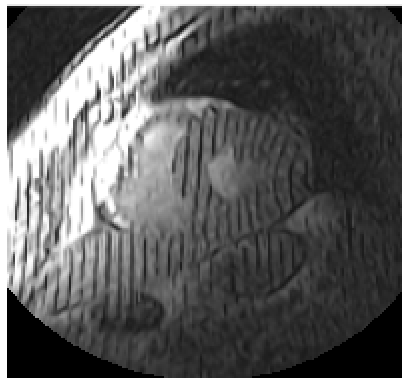
IR Prep Gated FGRE Sequence Protocol Example		
What You Select		**Selection Notes**
Additional Parameters - Graphic Rx		
		
[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.
Image Viewport	Click the image to display the line cursor.	Prescribe the slices from cardiac apex to base to display the graphic prescription. Select the adjustment handles to angle, draw, and remove slices. Position the slices to cover the anatomy of interest and view the Advisory Panel to note the maximum number of slices per acquisition and the number of acquisitions you are prescribing. The scan time increases as the number of acquisitions increase.
Copy Rx	**[Copy Rx]** (optional)	If you had previously graphically prescribed an oblique series with the same FOV and slice thickness, the prescription can be copied to the exact locations of the prior series.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Erase All	**[Erase All]** (If necessary)	Eliminates the graphic prescription from the screen and allows you to start over.
Accept	**[Accept]**	Confirms the cursor position and closes Graphic Rx Additional Parameter screen.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition.
Scan	**[Scan]**	Initiates the acquisition. Instruct the patient to hold his/her breath as long as possible, until the scan stops, if able.

Cardiac Images and Example Protocols

Wall Motion Sequence

The Wall Motion Sequence is the first series in the cardiac protocol and can be acquired with a FastCINE SPGR without tags or a FastCINE GRE with tags as shown in Figure 12-1. This sequence allows the assessment of the contractile function of the ventricular wall.

Figure 12-1 Short Axis FastCINE GRE with Tagging



GRE Tagged View

Table 12-4 Wall Motion Sequence Example

Plane	Mode	Pulse Sequence	TE	TR	Flip Angle	RBw	FOV	Slice Thickness	Slice Spacing	Matrix
Oblique	2D	FastCard SPGR (GRE if tagged)	Min Full	N/S	20	31.2	40	8.0	0.0	256x128

NEX	Phase FOV	Freq Direction	Center Frequency	AutoShim	Phase Correct	Imaging Options	Sat Pulses
1	0.75	Unswap	Water	On	Off	Cardiac Gating/ Triggering, FC, Sequential	Tags optional. Stripe or Grid. Choose pixel separation.

User CVs	Trigger Type	Arr Rej, Window	Trigger Delay	VPS	Phases	Multi Phase Options	Comments
Manual Arrhythmia Monitoring = 1	Select the Best Lead	50	Min	See VPS chart	20	N/A	Cardiac coil recommended

Cardiac Images and Example Protocols

Multi Phase FGR-ET Sequence

The Multi Phase FGR-ET Sequence is the second series in the cardiac protocol. This multi-slice sequence is typically repeated to acquire multiple phases of the cardiac cycle.

Table 12-5 Multi Phase FGR-ET Sequence Example

Plane	Mode	Pulse Sequence	TE/TI	TR	Flip Angle	ETL	RBw	FOV	Slice Thickness	Slice Spacing
Oblique	2D	FGRE-ET	Min/Auto	N/S	25	4	125	~32 to 40	10.0	0.0

Matrix	NEX	Phase FOV	Frequency Direction	Center Frequency	Auto Shim	Imaging Options	User CVs
128x128	1	0.75	Unswapped	Water	On	Cardiac Gating/ Triggering, VBw, MPh, IR Prep	Echo Tuning Mode:0 Echo Delay:0 Man Echo Align:0

Trigger Type	Trigger Window	Trigger Delay	R-Rs	Phases	Cine Options	Multi Phase Options	Comments
Select the Best Lead	5 to 10	Min	1 to 4	20	N/A	30 to 45	Cardiac coil recommended

IR Prep Gated FGRE Sequence

The last series in the cardiac protocol is acquired with a Fast GRE, IR Prep pulse sequence.

Table 12-6 IR Prep Gated FGRE Sequence Example

Plane	Mode	Pulse Sequence	TE/TI	TR	ETL #Shots	Flip Angle	RBw	FOV	Slice Thickness	Slice Spacing
Oblique	2D	Fast GRE	Min Full/ 200	N/S	N/A	20	31.25	~36	8.0	0.0

Matrix	NEX	Phase FOV	Frequency Direction	Center Frequency	Auto Shim	Phase Correct	Imaging Options	Vascular Options
256x192	2	0.75	Unswapped	Water	On	Off	Cardiac Gating/ Triggering, IR Prep	N/A

User CVs	Trigger Type	Trigger Window	Trigger Delay	R-Rs	VPS	Multi Phase Options	Comments
Perform Arrhythmia Rejection = 0	Select the Best Lead	20	60% of R-R Interval	1	24	N/A	Cardiac coil recommended

Chapter 13

FGRET Pulse Sequences

Introduction

Fast Gradient Echo-Echo Train (FGRET) is a Fast Gradient Echo (FGRE) sequence with an echo-planar (EPI) readout. FGRET uses a short repetition time (TR) gradient echo pulse sequence with the ability to acquire multiple views per TR using an EPI echo train (ET). Features of both the FGRE and EPI pulse sequences are combined for use in cardiac applications.

This chapter explains the pulsing components and timing factors directly related to the FGRET imaging pulse sequence. It contains the step-by-step instructions to help you learn how to:

- Prescribe the FGRET-MP Sequence
- Perform Manual Echo Alignment for the FGRET-MP Sequence
- Adjust Echo Alignment for the FGRET-MP Sequence
- Prescribe the FGRET-RT Sequence
- Perform Manual Echo Alignment for the FGRET-RT Sequence
- Adjust Echo Alignment for the FGRET-RT Sequence

In addition, this chapter answers the following questions:

1. What is FGRET?
2. When would I use the FGRET pulse sequence?
3. What methods can I use to acquire the FGRET pulse sequence?
4. What are the imaging characteristics of the FGRET pulse sequence?
5. Which imaging options can be used with the FGRET pulse sequence?
6. What are some applications for FGRET sequences?

What Do I Need to Know About...

This section presents the concepts necessary to understand imaging with FGRET pulse sequences. Specifically, you need to understand the following concepts:

- FGRET Basics
- Optimizing the User Control Variables
  - Echo Tuning And Alignment
  - Ramp Sampling
  - Turbo Acquisition Mode
- FGRET with Multi Phase
  - Parameter Selection Effects
  - Image Characteristics
  - Associated Imaging Options
  - Applications
- FGRET for Real Time
  - Parameter Selection Effects
  - Associated Imaging Options
  - Applications

FGRET Basics

FGRET uses a short TR, FGRE pulse sequence with the ability to acquire multiple views (phase encoding steps) per TR using an EPI ET. Features of both the FGRE and EPI pulse sequences are combined for use in cardiac applications. Refer to Table 13-1 for the features of FGRE and EPI that come together to compose the FGRET pulse sequence.

Table 13-1 FGRET Features

Fast Gradient Echo Features	EPI Features
Uniform RF excitation at minimum TRs	Interleaved gradient echo acquisition
Centric phase encoding	Acquisition of multiple views in one TR, the number of TRs being equal to the number of shots
Segmented k-space filling	
FASTCINE, retrospective gating in FastCard-ET	

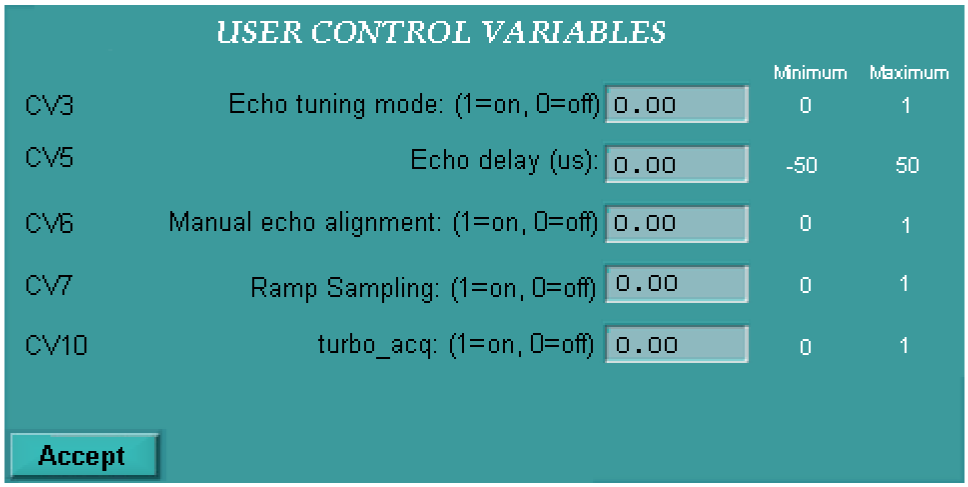
There are two methods for using FGRET.

- FGRET with Multi Phase (FGRET-MP)
  - This is a sequence that supports acquisition of a dynamic myocardial image series.
  - This is a multi-slice sequence used in conjunction with the Multi Phase Imaging Option. The sequence is generally repeated 30 to 60 times for observation of tissue changes over time.
  - Images are annotated “FGR/ET.” MP and EG (for Multi Phase and ECG Gating/Triggering, respectively) are annotated in the Imaging Options line.
- FGRET for Real Time (FGRET-RT)
  - This is a single-slice sequence that is initiated and controlled with the Signa® *i*Drive™ Pro Plus feature for Real Time Cardiac Acquisitions (RTCAs). When you enable it on your scanner, the data acquisition runs continuously.
  - Images are annotated “FGR/ET.” RT is annotated in the Imaging Options line of the image.

Optimizing User Control Variables

The FGRET-MP and FGRET-RT pulse sequences include several control variables accessed via the User Control Variables (User CVs) screen located in the Additional Parameters area. Selecting the **User CVs Screen** icon, opens the User CVs screen (Figure 13-1).

Figure 13-1 User CVs Screen for FGRET-MP and FRGET-RT



Echo Tuning and Alignment

FGRET-MP is susceptible to ghosting artifacts caused by phase errors that accumulate within the ET. Auto echo alignment is used by the system to compensate for these phase errors. Echo alignment is performed for each slice location at the start of each acquisition.

It is recommended that a trial acquisition be performed before the FGRET series. This acquisition can be used to evaluate the success of the auto echo alignment process. If it appears that there is an unacceptable amount of image blurring as in Figure 13-2, the manual echo alignment procedure can be performed. Alternatively, perform a manual echo alignment series rather than allowing the system to perform the alignment automatically.

Figure 13-2 Misaligned Echoes

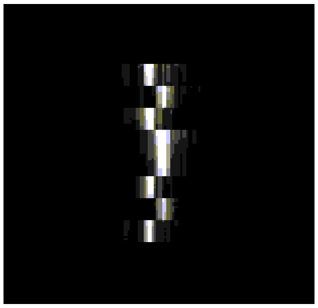
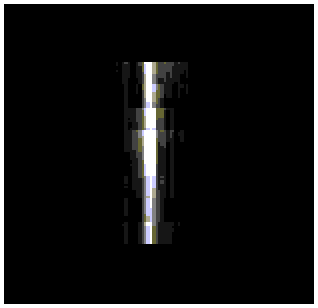


Figure 13-2 exhibits echoes that are misaligned by a few microseconds. By adjusting the echo delay, on the User CVs screen, the echoes can be brought more closely into alignment as shown in Figure 13-3.

Figure 13-3 Aligned Echoes



A trial FGRET-RT acquisition can be performed to evaluate the success of the auto echo alignment process. If it appears that there is an unacceptable amount of image blurring, the manual echo alignment procedure can also be performed.

Manual echo alignment is enabled on the User CVs screen. The CVs Echo tuning mode, Echo delay and Manual Echo Alignment are used to perform manual alignment. The default for these control variables is zero, meaning off. The procedure for manual echo alignment can be found in the **How Do I...** section; refer to Perform Manual Echo Alignment for the FGRET-MP or FRGET-RT Sequence.

NOTE: A properly calibrated MR imaging system is essential to obtain adequate image quality in ET pulse sequences. A service engineer performs system calibration.

Ramp Sampling

Ramp sampling can be used with FGRET sequences. Ramp sampling is performed in the same fashion as an EPI sequence. Ramp sampling expands the usable time during which an echo is acquired (or sampled).

Echo sampling takes place during the rise/fall portion of the readout gradient, as well as during the flat-top portion. The result is decreased echo spacing which, in turn, decreases image blurring. Note that when ramp sampling is enabled on the User CVs screen, the receive bandwidth (RBw) is set to 125 kHz and cannot be changed.

Turbo Acquisition Mode

Turbo acquisition mode allows a portion of the processing, generally completed during acquisition, to be completed during image reconstruction. The result is a decrease in data acquisition time, which provides an improvement in the frame rate. The frame rate is the number of images acquired per second. Turbo acquisition can increase the frame rate by as much as ten percent. The increased frame rate can be important when observing tissue enhancement. The trade-off to using the turbo acquisition mode is a slight increase in image ghosting or blurring. Turning on Ramp Sampling can mitigate these effects.

FGRET with Multi Phase

FGRET with Multi Phase (FGRET-MP) is a cardiac gated, multi-slice acquisition that supports acquisition of a dynamic myocardial image series. Multiple images are acquired at each slice location over a defined number of cardiac cycles. Each image at the same slice location is acquired at the same phase of the cardiac cycle. Therefore, the sequence is not intended to image a slice location at multiple phases of the cardiac cycle.

FGRET-MP acquires all data for one slice in a single cardiac cycle, and multiple slice locations can be acquired within that cardiac cycle if time allows. Selecting Fast GRE ET on the Pulse Sequence window, as well as, Cardiac Gating/Triggering and Multi Phase on the Imaging Options window sets up the sequence. The sequence is typically repeated 30 to 60 times, obtaining a large number of images at each location over a period of time. Each slice location is obtained at the same phase of the cardiac cycle.

After selecting Multi Phase on the Imaging Options window, the Multi Phase screen is used to define the number of times the sequence repeats. This is set as Phases per Location on the Multi Phase screen. If 6 slice locations are prescribed and Phases per Location is set to 30, a total of 180 images will be obtained. Thirty images will be acquired at each location.

The maximum number of slices per acquisition depends on the patient's heart rate, the number of R-R intervals, the ETL, TR, and frequency matrix. Also, a maximum of 64 locations and 512 total images can be prescribed. This means the total number of images in FGRET-MP sequences is based on Equation 13-1.

Equation 13-1 FGRET-MP Total Number of Images

(Number of Phases X Number of Locations) = 512

FGRET-MP allows the selection of one, two, three or four R-R intervals on the Cardiac Gating/Triggering screen, resulting in cross R-R imaging.

- When 1 x R-R is used, a complete image of all slice locations is acquired every cardiac cycle.
  - When 1 x R-R is used, the images are acquired in a sequential fashion within one cardiac cycle (e.g., the data for six slices would be obtained in this order; 1, 2, 3, 4, 5, 6).
    - An exception to this is when 1 x R-R is used and Inversion Recovery (IR) Prepared is turned on. In this case, the slices are acquired in an interleaved fashion (e.g., six slices are collected in this order, 1, 3, 5, 2, 4, 6).
- If 2 x R-R is selected, the prescribed slices are acquired across two cardiac cycles.
  - For example, if 6 slice locations are prescribed, images 1, 3, and 5 are acquired across the first cardiac cycle. Images 2, 4, and 6 are then acquired within the second cardiac cycle.
- 2 x R-R (or greater) can be used for obtaining full coverage through the heart when the patient's heart rate is above 80 BPM and all slices cannot be acquired in one cardiac cycle.

The number of slice locations prescribed can be either an odd or even number. Prescribe your slices from the cardiac apex to the base for improved image quality at the cardiac apex. Also, prescribe the maximum number of slice locations allowed per R-R interval to prevent degradation of the first slice images acquired in the sequence.

Parameter Selection Effects

The sequence parameters have different effects that contribute to the FGRET-MP images. The following parameter selections are compatible with FGRET-MP:

- Phased array
- Phase field of view (FOV) less than one (0.5 and 0.75)
- RBw from 32 to 125 kHz
- ETL of 2, 4, 8, or 12
- Number of excitations (NEX) is not selectable, 1 NEX is automatically used. Therefore, adjust other scan parameters to increase SNR.

The following factors can be affected by altering the values for a particular parameter:

- Contrast
- Resolution
- Temporal resolution

Factors that affect Contrast

FGRET-MP can also use a saturation prep-pulse by selecting IR Prepared on the Imaging Options window. IR Prepared can be used to suppress the myocardium and enhance T1 contrast so the tissue is better visualized. An added benefit is the inversion times (TI) used also provide some fat suppression.

The prep-pulse used is a notched pulse; it is applied at a width covering half the number of prescribed slice locations on either side of the current slice. The prep-pulse prepares the next slice prior to acquisition of the current slice. The TI times are longer than the time it takes to acquire a slice. The prep time (TI time) is calculated automatically based on sequence parameters and cannot be edited. The actual TI time is annotated on the images; e.g., TI:173.

The flip angle for this sequence is typically set between 15° to 25°. The optimal flip angle is 25°, causing the myocardium to be darker.

Note that the prep pulse is not applied to the first slice location; therefore, the image contrast for that slice differs from the remaining slices. Also, when FGRET-MP is used in conjunction with IR Prepared, the slices are acquired in an interleaved fashion even when 1 x R-R interval is selected.

Factors that Affect Resolution

The FOV you select should be the size of the patient to obtain optimal image resolution for the anatomy being examined. Anatomy outside the FOV in the phase directions wraps into the image since NPW is not compatible with FGRET. Keep in mind that you can use 0.75 Phase FOV as well.

The slice thickness you choose should be between 8 to 10 mm to cover the heart. An 8 mm slice thickness produces better resolution, but the 10 mm slice thickness may produce a better signal-to-noise ratio (SNR).

Your frequency and phase matrix choices should be 128x128 for optimal resolution, echo spacing, and SNR. The phase matrix also controls scan time and cannot exceed the value of the frequency matrix.

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Factors that Affect Temporal Resolution

Temporal resolution is related to the number of phases acquired in the least amount of time. Table 13-2 describes what effect specific parameters have on temporal resolution in the FGRET sequence.

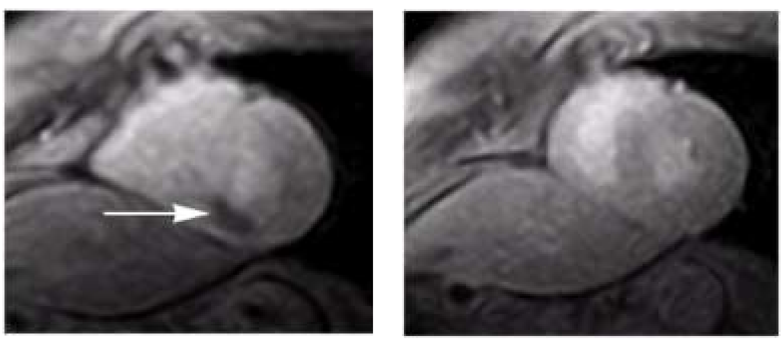
Table 13-2 Effects on Temporal Resolution

Parameter	Temporal Resolution
⇑ TR	⇓
⇑ ETL	⇑
⇑ Bandwidth	⇑
⇑ Phase FOV	⇓

Image Characteristics

FGRET-MP demonstrates an assessment of myocardial tissue. This sequence allows high temporal resolution, while applying sufficiently long inversion time to allow T1 weighting. FGRET-MP images can also be acquired under cardiac stress and rest conditions as shown in Figure 13-4.

Figure 13-4 Images acquired with the FGRET sequence. Note the filling defect is only noticeable on the image that was acquired under stress conditions.



FGRET
Representing a defect under stress conditions.

FGRET
No defect under rest conditions.

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 13-3, the X's indicate the imaging options available for use with the FGRET-MP pulse sequence.

Table 13-3 FGRET-MP Pulse Sequence Imaging Options

Imaging Options			
	None	**X**	Variable Bandwidth
X	Flow Compensation		No Phase Wrap
	POMP		Extended Dynamic Range
X	Square Pixel	**X***	Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer		Sequential
X	Cardiac Gating/Triggering		Respiratory Gating/Triggering
	Tailored RF	**X**	IR Prepared
	DE Prepared	**X**	Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024		ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

NOTE: *Surface Coil Intensity Correction (SCIC) is available with the Torso coil. There are no SCIC parameters for the Cardiac coil.

Applications

FGRET-MP imaging can be used in clinical applications to obtain myocardial images with high temporal resolution.

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WARNING: The system cardiac gating waveforms are not to be used for physiologic monitoring. The patient's condition may not be reflected, resulting in improper emergency medical treatment.

FGRET for Real Time

FGRET for Real Time (FGRET-RT) is a fast gradient echo-echo train sequence performed using RTCA with Signa *i*Drive Pro Plus to obtain real time image data with interactive scan plane manipulation.

FGRET-RT, sometimes called "fluoro" mode, has been developed to provide real time localization of cardiac anatomy. FGRET-RT is prescribed in the same manner as any *i*Drive RTCA series. Once data acquisition is initiated on the Acquire tab, the data acquisition runs continuously. Your input is required on the Acquire tab to manipulate the scan plane, but Acquire tab Image Contrast tools are not available for FGRET-RT. You can review and save the images in the same fashion as any other *i*Drive image.

NOTE: Refer to Real Time Imaging chapter in this guide for additional information on *i*Drive Pro Plus.

Due to the large ETs used in FGRET-RT, the sequence is susceptible to ghosting artifacts caused by phase errors. The use of fat saturation (SAT) and low flip angles may help decrease the blurring that occurs with FGRET-RT imaging. FGRET-RT also provides auto echo alignment, which is performed to compensate for these phase errors.

Auto echo alignment is performed each time the scan plane is changed during the FGRET real time session. As a result, there are some images acquired as echo alignment is taking place, and these images may exhibit blurring.

Manual echo alignment, a feature also accessed on the User CVs screen, can be used to check and adjust the echo alignment prior to starting the real time data acquisition. Manual echo alignment is not commonly used with FGRET-RT. Refer to this section (**What Do I Need to Know About...**) for details on the User CVs screen, and the Manual Echo Alignment procedure in the **How Do I...** section for details on how to perform manual alignment.

There are several factors you should consider when using FGRET-RT:

- As in any *i*Drive RTCA prescription, only one location is prescribed.
- Spatial SAT pulses are not allowed.

Parameter Selection Effects

The sequence parameters have different effects that contribute to the FGRET-RT images. The following factors can be affected by altering the values for a particular parameter:

- Contrast
- Resolution
- Frame rate

Factors that Affect Contrast

Images acquired with RTCA can display different types of contrast. Image contrast can be controlled by Fat SAT and Flow Compensation (FC). These selections can be prescribed during series prescription. FC and Fat SAT are not available on the Pro Plus Acquire tab to turn on or off. The use of Fat SAT and low flip angles may help compensate for the image blurring that occurs with FGRET-RT. Water SAT is not allowed. The Contrast tools on the Pro Plus Acquire tab: IR, SAT, Fat SAT, SPGR, and FC, are not available for FGRET-RT.

Factors that Affect Resolution

Prescribe a FOV that covers the anatomy of interest. Small FOVs produce increased resolution, decreased SNR, and may increase the minimum TE. Keep in mind that anatomy outside of the phase FOV could result in aliasing. Refer to Table 13-4 for additional parameter selections that affect image resolution with FGRET-RT.

Table 13-4 Effects on Resolution

Parameter	Resolution
⇑ Slice Thickness	⇓
⇑ Frequency Matrix	⇑
⇑ Phase Matrix	⇑
Square Pixels	⇑

Factors that Affect Frame Rate

Several series parameters affect the frame rate (FPS) during real time data acquisition. Frame rate can be affected by the parameters shown in Table 13-5. RBw affects the readout time. As bandwidth increases, the system samples faster during the echo which decreases the minimum TR. The frequency matrix also affects the readout time. As the frequency matrix increases, the system must read more samples during the echo which increases the minimum TR.

Table 13-5 Affects on Frame Rate

Parameter	Frame Rate
⇑ RBw	⇑
Fat Sat	⇓
⇑ ETL	⇑
⇑ Frequency Matrix	⇓

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 13-6, the Xs indicate the imaging options available for use with the FGRET-RT pulse sequence.

Table 13-6 FGRET-RT Pulse Sequence Imaging Options

Imaging Options			
	None	**X**	Variable Bandwidth
X	Flow Compensation		No Phase Wrap
	POMP		Extended Dynamic Range
X	Square Pixel		Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer		Sequential
	Cardiac Gating/Triggering		Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024		ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station	**X***	Real Time
	T2 Prep		Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

NOTE: *Real Time must be selected to acquire FGRET-RT images.

Applications

FGRET-RT can be used to quickly obtain localizer images and locations for imaging cardiac anatomy, as well as other areas of the body.

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How Do I...

This section provides the step-by-step instructions for prescribing FGRET imaging pulse sequences and for performing manual echo alignment. Specifically, it describes how to:

- Prescribe the FGRET-MP Sequence
- Perform Manual Echo Alignment for the FGRET-MP Sequence
- Adjust Echo Alignment for the FGRET-MP Sequence
- Prescribe the FGRET-RT Sequence
- Perform Manual Echo Alignment for the FGRET-RT Sequence
- Adjust Echo Alignment for the FGRET-RT Sequence

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the “What You Select” column of the matrix uses two other conventions.

- N/A indicates that the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates that the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

CAUTION: **Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.**

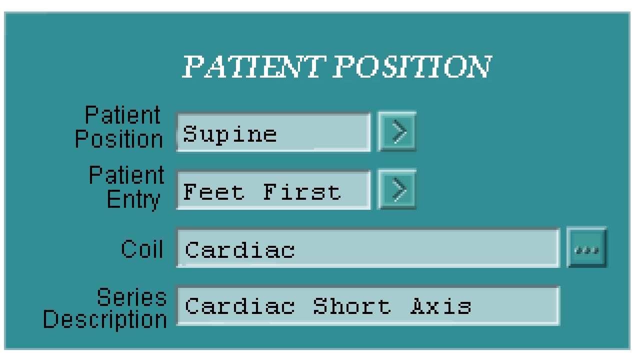
Prescribe the FGRET-MP Sequence

The FGRET-MP sequence is useful in clinical applications to obtain myocardial images. It is a cardiac gated sequence with the Multi Phase Imaging Option. Multiple images are acquired at each slice location over a defined number of cardiac cycles. Each slice location is obtained at the same phase of the cardiac cycle. This sequence also uses IR Prepared to suppress the myocardium and enhance T1 contrast so that the tissue is better visualized.

The decision matrix (Table 13-7) is only for prescribing the FGRET-MP sequence. The following example protocol is for prescribing an oblique short axis cardiac scan for a TwinSpeed™ or an EchoSpeed™ system.

Table 13-7 FGRET-MP Protocol Example (Short Axis Cardiac)

FGRET-MP Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Scan Rx	Acquire a localizer series	Allows Graphic Rx to become available so you can prescribe slices graphically on the localized image.
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol window becomes active.
Patient Position		



Patient Position	**Supine**	Indicates the orientation of the patient. Although compatible with any patient position and entry, supine and feet first are recommended. This Ensures accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	

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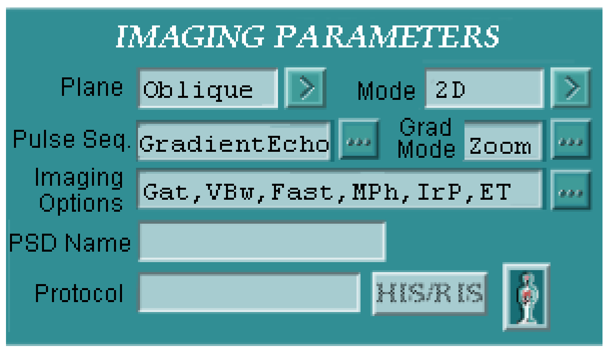
FGRET-MP Protocol Example		
What You Select		**Selection Notes**
Coil	**Phased Array > Cardiac**	Allows selection of the coil from which the signal is transmitted and received. Use a coil that produces the optimum coverage and SNR.
Series	Enter a series description in the text box.	Allows you to enter a brief description of the series being prescribed. If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

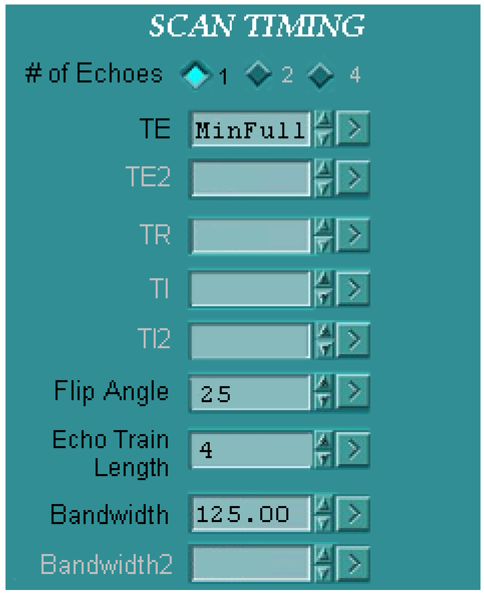
Imaging Parameters



Plane	**Oblique**	Defines the scan plane of the acquisition. Compatible with any scan plane. Select the plane that best meets your clinical need. For cardiac short or long axis imaging, select oblique for proper angle through the heart.
Mode	**2D**	Prescribes a two-dimensional sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Seq.	**Fast GRE ET**	Prescribes the FGRET pulse sequence.
Imaging Options	**Cardiac Gating Triggering**, **Variable Bandwidth**, **Multi-Phase**, and **IR Prepared**	Provides appropriate options for enhancing anatomical features and reducing noise. Cardiac Gating/Triggering should be selected. Multi Phase acquires multiple images at each slice location. IR Prepared improves T1 contrast.
PSD Name	N/A	
Protocol	N/A	

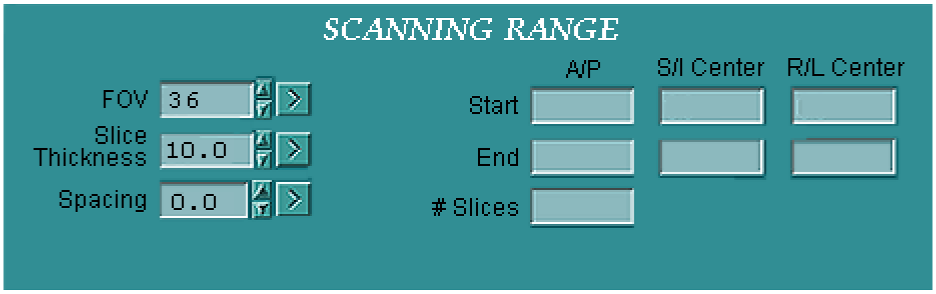
FGRET-MP Protocol Example		
What You Select		Selection Notes

Scan Timing



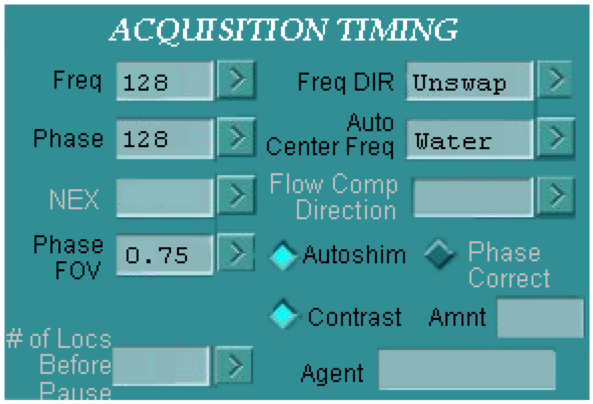
# of echoes	N/S	One echo is selected automatically.
TE	**Min Full**	The only selection available is minimum full.
TE2	N/A	
TR	N/S	The minimum TR is selected automatically. The minimum TR decreases as RBw increases, and as ETL, frequency matrix, and obliquity decrease.
TI	N/S	The TI is automatically calculated based on the other sequence parameters. The TI is generally in the range of 150 to 175 ms when 0.75 PFOV is selected. Otherwise, the TI is >230 ms, causing poor fat suppression.
TI2	N/A	
Flip Angle	Enter **25** in the text box.	The typical flip angle value is 25°.
Echo Train Length	**4**	As the ETL is increased, TR increases, and image blurring increases. Note the (phase matrix x PFOV) must be an even multiple of the ETL. The system posts a message if this is not followed.
Bandwidth	**125**	The typical RBw value is 125 kHz. Generally, wider bandwidths are used to minimize TR and TE values.
Bandwidth2	N/A	

FGRET-MP Protocol Example		
What You Select		**Selection Notes**
Scanning Range		



FOV	**36**	Defines the size of the area imaged. Select an FOV that covers the anatomy of interest, about 32 to 40 cm. Anatomy outside the FOV in the phase direction results in aliasing. Small FOVs produce increased resolution, decreased SNR, and can increase the minimum TE value.
Slice Thickness	**10.0**	Defines the thickness of the image slice. 10 mm is generally used to obtain coverage through the entire heart on the first pass sequence.
Spacing	Enter **`0.0`** in the text box.	Places a zero spacing between the prescribed slice locations. Zero spacing is used for complete coverage.
Start, End Locations		Determines the start and end locations from the Graphic Rx program after the slices are prescribed and posts the locations here.
# Slices		Determines the number of slices as prescribed in Graphic Rx and posts it here. Adjust the number of slice locations as necessary. The maximum number of slices per acquisition depends on the heart rate, the number of R-R intervals, the ETL, TR, and frequency matrix.

FGRET-MP Protocol Example		
What You Select		**Selection Notes**
Acquisition Timing		

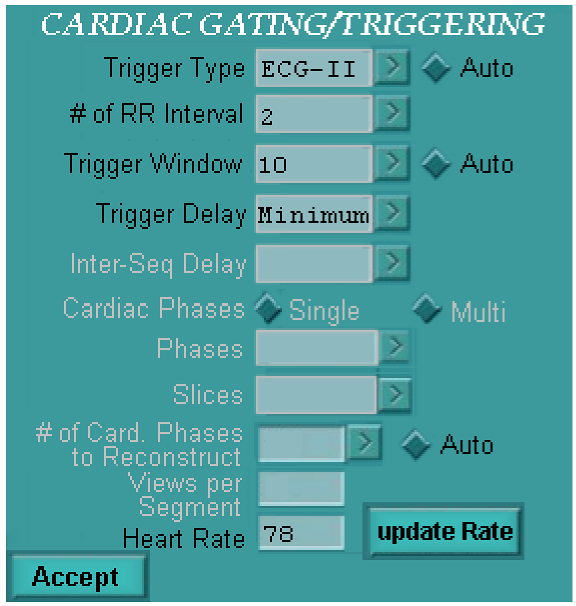


Freq	**128**	Controls resolution. Increasing the frequency matrix decreases echo space, SNR, the number of slice locations allowed, while increasing resolution. Available selections are 128 to 256, in steps of 32.
Phase	**128**	Controls scan time and resolution. The phase matrix cannot exceed the frequency matrix. Available selections are 64 to 256, in steps of 32. Note the (phase matrix x PFOV) must be an even multiple of the ETL.
NEX	N/S	One NEX is used automatically.
Phase FOV	**0.75**	Shortens scan time by scaling down the FOV in the phase direction by either 0.5 or 0.75. A full PFOV of one is also available to prevent wrapping of anatomy. Reduce the phase matrix to decrease scan time, FOV in the phase direction, and SNR (slightly). Note the (phase matrix x PFOV) must be an even multiple of the ETL. Due to effects on TI, 0.75 PFOV is recommended for optimum fat suppression.
Freq DIR	**Unswap**	Displays the default frequency direction which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	Sets this CF peak during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Improves image quality and is recommended for this sequence.
Phase Correct	N/A	
# of Locs Before Pause	N/A	

FGRET-MP Protocol Example

What You Select		Selection Notes

Additional Parameters - Gating/Triggering

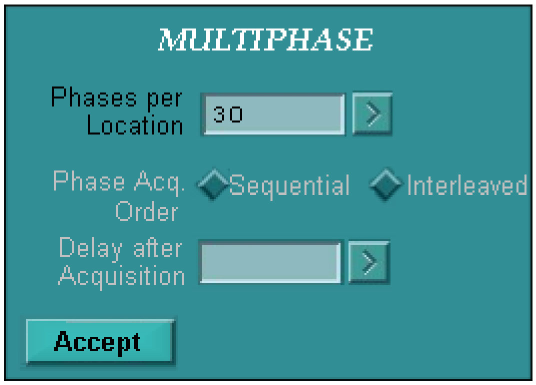


Trigger Type	Select the best lead.	Defines which signal is sent by the cardiac monitor to activate the data acquisition. When ECG gating, select the lead that provides the best signal.
# of R-R Interval	**2**	Defines the time between the peak of one R-wave and the peak of the next one. Usually 2 R-R intervals allow complete coverage of the heart. 1, 2, 3, or 4 x R-R Interval is available. As the heart rate increases, a larger R-R Interval is needed for complete coverage of the heart.
Trigger Window	**10**	Defines the period of time where no data is acquired and when the system is waiting for the next R-wave trigger. Values of 10 to 15 are most commonly used. As the TW increases, the number of slice locations allowed decreases. Use larger values on patients with irregular heart rates. Actual scan times are longer than expected if triggers are detected outside the TW.
Trigger Delay	**Minimum**	Defines the delay time between the occurrence of the triggering pulse and the actual onset of imaging. The most minimum TD is desired to cover the full R-R interval.
Inter-Seq Delay	N/A	
Cardiac Phases	N/A	
# of Card. Phases to Reconstruct	N/A	
Views per Segment	N/A	

FGRET-MP Protocol Example

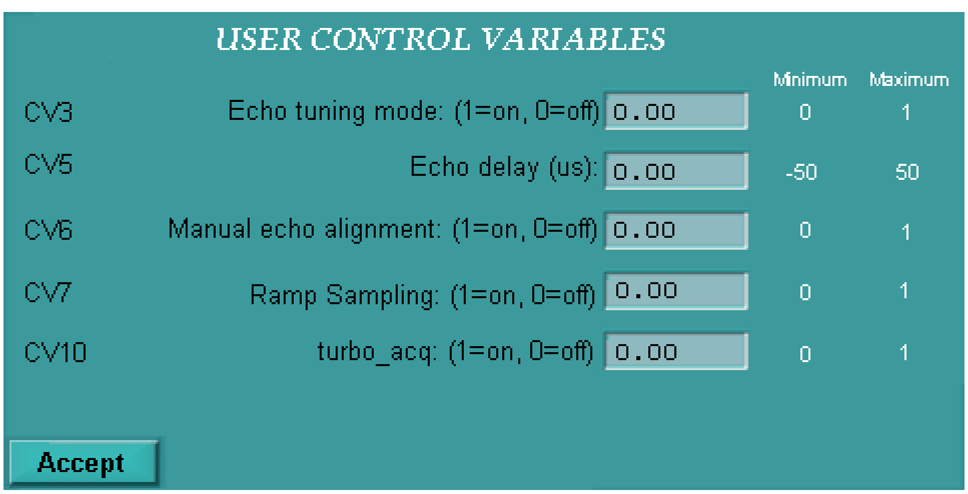
What You Select		Selection Notes
Heart Rate	**[update Rate]**	Lets the system obtain an automatic reading of the current heart rate. Updates the rate prior to beginning the scan.
Accept	**[Accept]**	Confirms the selected values and closes Gating/Triggering Additional Parameter screen.

Additional Parameters - Multi Phase



Phases per Location	Enter **30** in the text box.	Defines the number of times the sequence repeats, and therefore, the number of images acquired for each slice location. Typically select 30 to 60 phases.
Phase Acq. Order	N/A	
Delay after Acquisition	N/A	
Accept	**[Accept]**	Confirms the selected value and closes Multi Phase Additional Parameter screen.

Additional Parameters - User CVs



Echo tuning mode	**0.00**	All User CVs for this sequence are turned off (0=off). Refer to the **What Do I Need to Know About...** section for the discussion on Manual Echo Alignment.
Echo delay	**0.00**	

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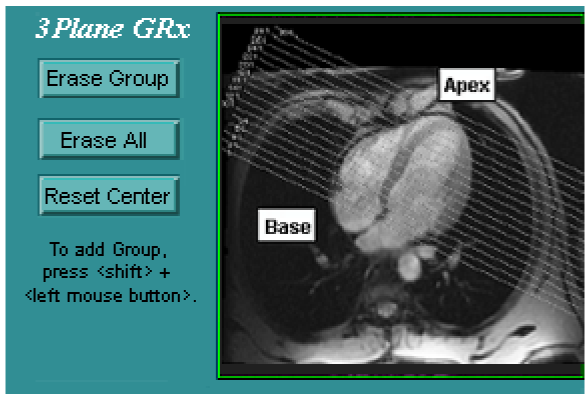
FGRET-MP Protocol Example		
What You Select		**Selection Notes**
Manual echo alignment	**0.00**	
Ramp Sampling	**0.00**	
turbo_acq	**0.00**	
Accept	**[Accept]**	Confirms the selected values and closes the User CVs Additional Parameter screen.
Additional Parameters - Graphic Rx		



[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.
Image Viewport	Click the image to display the line cursor.	Allows you to prescribe slices from the cardiac apex to the base for graphic prescription. Select the adjustment handles to angle, draw, and remove slices. Position the slices to cover anatomy of interest and view the Advisory Panel to note the maximum number of slices per acquisition and the number of acquisitions you are prescribing. The scan time increases as the number of acquisitions increase.
Copy Rx	**[Copy Rx]** (optional)	Copies the exact locations of the prior series if you had previously graphically prescribed a series with the same plane, FOV, and slice thickness.
Erase All	**[Erase All]** (If necessary)	Eliminates the graphic prescription from the screen and allows you to start over.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Accept	**[Accept]**	Confirms the cursor position and closes Graphic Rx.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.

FGRET-MP Protocol Example		
What You Select		**Selection Notes**
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition. Select for breath-hold acquisitions.
Scan	**[Scan]**	Initiates the acquisition. Instruct the patient to hold his/her breath as long as possible, until the scan stops, if able.

Perform Manual Echo Alignment for the FGRET-MP Sequence

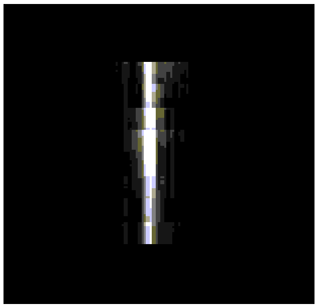
Manual Echo Alignment can be performed after performing a trial series if image quality is in question, or this procedure can be performed instead of a trial series. This process allows a manual check of the echo alignment to ensure optimum image quality. Even when this procedure is performed, image quality can be affected by phase offsets which are inherent to ET sequences. This procedure guides you through the process of manually aligning the echoes for the FGRET-MP sequence.

1. Prescribe the series to be used for the FGRET-MP acquisition.
   - Refer to the FGRET-MP decision matrix.
2. Turn IR Prepared off.
   - Located on the Imaging Options window.
3. Click the **User CVs Screen** icon.
   - Located in the Additional Parameters area.
4. Enter **1** in the **Echo tuning mode** text box.
   - Prompts the system to display a representation of the echoes from which proper alignment can be assessed.
5. Click **[Accept]**.
   - Accepts the entry and closes the User CVs screen.
6. Click the **Multi Phase Screen** icon.
   - Located in the Additional Parameters area.
7. Enter **1** in the **Phases per location** text box.
   - Prescribes one phase per slice location.
8. Click **[Accept]**.
   - Accepts the entry and closes the Multi Phase screen.
9. Click the **Graphic Rx** icon.
   - Located in the Additional Parameters area.
10. Prescribe one slice location through the center of the anatomy.
    - The slice angle, FOV, RBw, and matrix values must be exactly the same as the FGRET series.

Quick Steps: Perform Manual Echo Alignment for the FGRET-MP Sequence

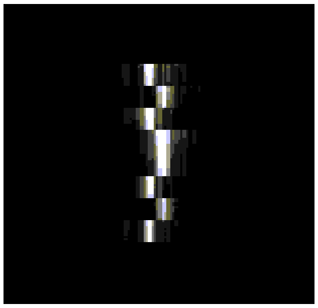
1. Prescribe the series to be used for the FGRET-MP acquisition.
2. Turn IR Prepared off.
3. Click the **User CVs Screen** icon.
4. Enter **1** in the **Echo tuning mode** text box.
5. Click **[Accept]**.
6. Click the **Multi Phase Screen** icon.
7. Enter **1** in the **Phases per location** text box.
8. Click **[Accept]**.
9. Click the **Graphic Rx** icon.
10. Prescribe one slice location through the center of the anatomy.
11. Click **[Accept]**.
12. Click **[Save Series]**.
13. Click **[Prepare to Scan]**.
14. Click **[Scan]**.
15. Evaluate the images.
16. Prescribe the FGRET-MP pulse sequence.

11. Click **[Accept]**.
    - Accepts the prescription and closes the Graphic Rx screen.
12. Click **[Save Series]**.
    - Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
13. Click **[Prepare to Scan]**.
    - Downloads the series.
14. Click **[Scan]**.
    - Auto Prescan is performed and the system initiates the data acquisition with Echo tuning mode on.
15. Evaluate the images.
    - If the echoes are aligned, continue with step16.



Aligned Echoes

    - If the echoes are misaligned, adjust the echo alignment using the Adjust the Echo Alignment for the FGRET-MP Sequence procedure.



Misaligned Echoes

16. Prescribe the FGRET-MP pulse sequence.
    - Refer to the FGRET-MP decision matrix.
    - Set the Manual echo alignment to zero.

Adjust Echo Alignment for the FGRET-MP Sequence

Use this procedure if you have performed a manual echo alignment of the FGRET-MP pulse sequence and the echoes are misaligned. Another series must be acquired to adjust the echo alignment. This procedure guides you through the process of adjusting the echo delay to bring the echoes more closely into alignment.

1. Copy and paste the FGRET-MP series used in the Manual Echo Alignment process.
2. Click **[View Edit]**.
   - Opens the series and allows for changes.
3. Click the **User CVs Screen** icon.
   - Located in the Additional Parameters area.
   - The User CVs return to their default state when a new series is selected.
4. Enter **1** in the **Echo tuning mode** text box.
   - Prompts the system to display a representation of the echoes from which proper alignment can be assessed.
5. Enter **6** in the **Echo delay** text box.
   - Values from ±1 to ±12.
     – The delay unit is microseconds.
6. Enter **1** in **Manual echo alignment** text box.
   - Enables manual alignment.
7. Click **[Accept]**.
   - Accepts the entries and closes the User CVs screen.
8. Click **[Save Series]**.
   - Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
9. Click **[Prepare to Scan]**.
   - Downloads the series.
10. Click **[Scan]**.
    - Auto Prescan is performed and the system initiates the data acquisition with Echo tuning mode on.

Quick Steps: Adjust Echo Alignment for the FGRET-MP Sequence

1. Copy and paste the FGRET-MP series used in the Manual Echo Alignment process.
2. Click **[View Edit]**.
3. Click the **User CVs Screen** icon.
4. Enter **1** in the **Echo tuning mode** text box.
5. Enter **6** in the **Echo delay** text box.
6. Enter **1** in **Manual echo alignment** text box.
7. Click **[Accept]**.
8. Click **[Save Series]**.
9. Click **[Prepare to Scan]**.
10. Click **[Scan]**.
11. Evaluate the images.
12. Repeat the acquisition, changing the echo delay each time, until the echoes are aligned as well as possible.
13. Record the value of the optimal echo delay.
14. Prescribe the FGRET-MP pulse sequence.
15. Enter the echo values on the User CVs screen.
16. Scan the FGRET-MP pulse sequence.

11. Evaluate the images.
    - If the echoes are aligned, continue with step 13.
    - If the echoes are misaligned continue with step 12.
12. Repeat the acquisition, changing the echo delay each time, until the echoes are aligned as well as possible.
    - Continue to repeat steps 1 to 11 to adjust the echo delay value.
    - Adjust the echo delay in increments of one.
      – This may be a negative value.
13. Record the value of the optimal echo delay.

NOTE: If you are unable to align the echoes, contact your service engineer.

14. Prescribe the FGRET-MP pulse sequence.
    - Refer to the FGRET-MP decision matrix.
    - The slice locations must be the same obliquity as the location used for the manual echo alignment series.
15. Enter the echo values on the User CVs screen.
    - Echo tuning mode = 0
      – Zero is off.
    - Echo delay = the value determined in step 13.
    - Manual echo alignment = 1
      – One is on.
16. Scan the FGRET-MP pulse sequence.
    - Refer to the FGRET-MP decision matrix.

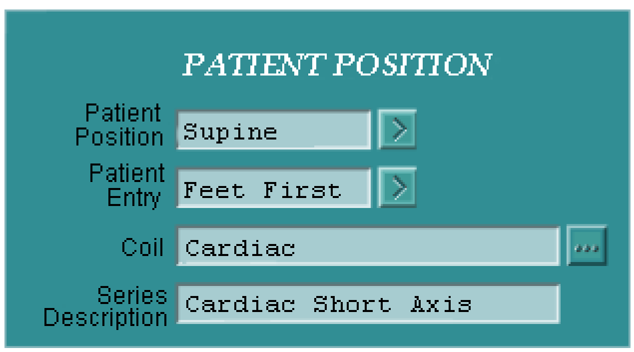
Prescribe the FGRET-RT Sequence

The FGRET-RT sequence is performed using *i*Drive Pro Plus for RTCAs to obtain real time image data with interactive scan plane manipulation. This is useful to quickly obtain localizer images and locations for imaging cardiac anatomy, as well as other areas of the body.

The decision matrix (Table 13-8) is only for prescribing the FGRET-RT scan. The following example protocol is for prescribing a real time scan for obtaining localizer images for imaging cardiac anatomy on a TwinSpeed or an EchoSpeed system.

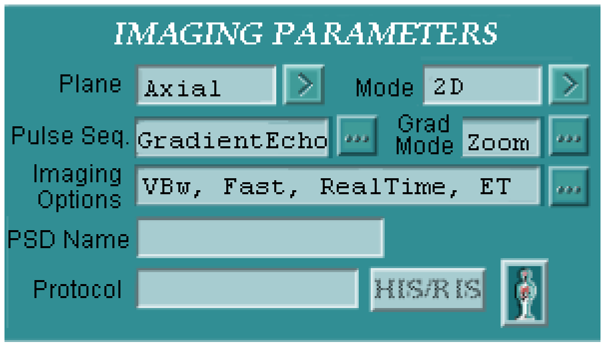
Table 13-8 FGRET-RT Protocol Example (Cardiac Localizers)

FGRET-RT Protocol Example		
What You Select		**Selection Notes**
	Rx Manager	
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol screen becomes active.
	Patient Position	



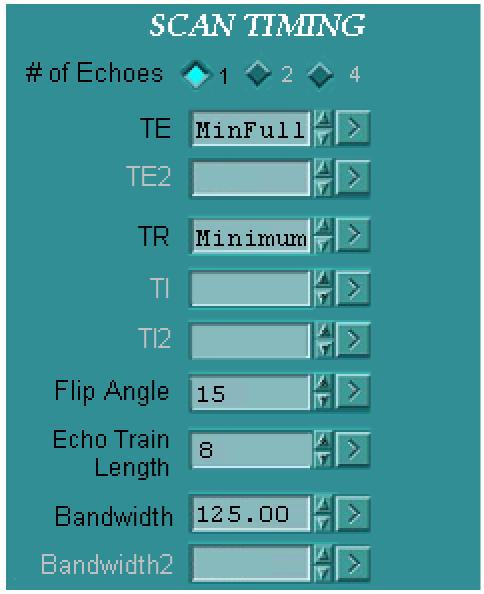
Patient Position	**Supine**	Indicates the orientation of the patient. Although compatible with any patient position and entry, supine and feet first are recommended. This ensures accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	
Coil	**Phased Array > Cardiac**	Allows selection of the coil from which the signal is transmitted and received. Use a coil that produces the optimum coverage and SNR.
Series Description	Enter a series description in the text box.	Allows you to enter a brief description of the series being prescribed. If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

FGRET-RT Protocol Example		
What You Select		**Selection Notes**
Imaging Parameters		



Plane	**Axial**	Defines the scan plane of the acquisition. Any orthogonal scan plane is allowed to set up the first slice in this real time sequence.
Mode	**2D**	Prescribes a two-dimensional sequence. 2D is the only mode allowable for real time sequences.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Sequence	**Fast GRE ET**	Prescribes the FGRET pulse sequence.
Imaging Options	**Real Time**, **Variable Bandwidth**	Provides appropriate options for enhancing anatomical features and reducing noise. Real Time enables FGRET-RT. VBw is available, but not necessary to alter the RBw. Square Pixels and FC are the only other available options.
PSD Name	N/A	
Protocol	N/A	

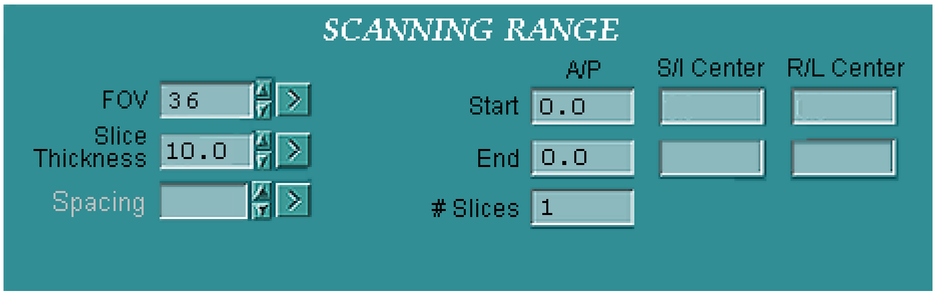
FGRET-RT Protocol Example		
What You Select		**Selection Notes**
Scan Timing		



# of echoes	N/S	One echo is selected automatically.
TE	**Min Full**	The only available selection is minimum full.
TE2	N/A	
TR	**Minimum**	The minimum TR is the only available selection. The minimum TR decreases as RBw increases, and as ETL, frequency matrix, and obliquity decrease.
TI	N/A	
TI2	N/A	
Flip Angle	Enter **15** in the text box.	The typical flip angle value is between 12° and 15° to help minimize image blurring.
Echo Train Length	**8**	As the ETL is increased, image blurring increases, the frame rate increases, and scan time decreases. 2, 4, 8, and 12 ETLs are allowed. You may want to decrease this value if you are operating a HiSpeed™ or SmartSpeed™ system.
Bandwidth	**125**	As the RBw increases, SNR decreases, minimum TE and TR values result, and image blurring decreases as a result of shorter echo spaces. 32, 62.5, and 125 kHz are allowed.
Bandwidth2	N/A	

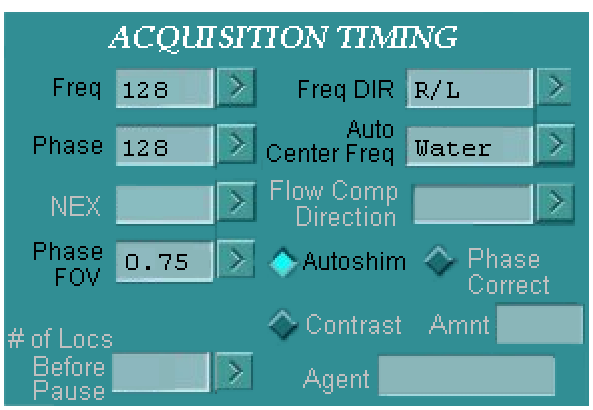
FGRET-RT Protocol Example

What You Select		Selection Notes
Scanning Range		



FOV	**36**	Defines the size of the area imaged. Select an FOV that covers the anatomy of interest, about 32 to 40 cm. Anatomy outside the FOV in the phase direction results in aliasing. Small FOVs produce increased resolution, decreased SNR, and can increase the minimum TE value.
Slice Thickness	**10.0**	Defines the thickness of the image slice. 8 mm to 10 mm is generally used to obtain the home images. This value can be interactively changed during data acquisition.
Spacing	N/A	FGRET-RT is a single slice acquisition; spacing is not required.
Start, End Locations	**0.0**	Determines the start and end locations. Either Explicit or Graphic Rx can be used to prescribe the single slice location.
# Slices	**1**	Determines the number of slices as prescribed in Explicit or Graphic Rx and posts it here. Only one slice location is allowed for real time sequences.

Acquisition Timing



Freq	**128**	Increasing the frequency matrix decreases echo space, SNR, the number of slice locations allowed, while increasing resolution. Available selections are 64 to 256, in steps of 32.

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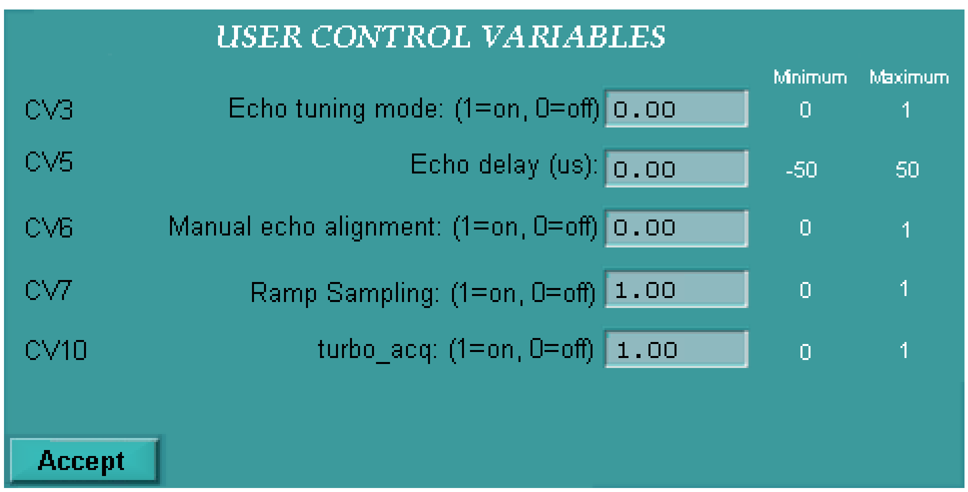
FGRET-RT Protocol Example		
What You Select		**Selection Notes**
Phase	**128**	The typical value is 96 or 128. The phase matrix cannot exceed the frequency matrix.
NEX	N/S	One NEX is used automatically.
Phase FOV	**0.75**	Select a phase FOV of one to prevent wrapping of anatomy. Choices are 1.0, 0.75, and 0.5. Reduce the phase matrix to decrease scan time, FOV in the phase direction, and SNR (slightly). The phase FOV dimension is displayed next to the phase FOV factor.
Freq DIR	**R/L**	Displays the default frequency direction which is typically the long axis of the image. To swap phase and frequency, select the other direction.
Auto Center Freq	**Water**	Sets this CF peak during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Improves image quality and is recommended for this sequence.
Phase Correct	N/A	
# of Locs Before Pause	N/A	

Additional Parameters - User CVs



Echo tuning mode	**0.00**	Manual echo alignment is not commonly performed on FGRET-RT. Refer to the **What Do I Need to Know About...** section for the discussion on manual echo alignment.
Echo delay	**0.00**	
Manual echo alignment	**0.00**	
Ramp Sampling	**1.00**	Decreases the echo space and image blurring. The RBw is fixed at 125 kHz when ramp sampling is enabled. Enter **1** in the text box to use ramp sampling. Leave the text box at the default value of zero if ramp sampling is not desired.

FGRET-RT Protocol Example		
What You Select		**Selection Notes**
turbo_acq	**1.00**	Decreases data acquisition times and increases the frame rate. Enter **1** in the text box to use turbo acquisition mode. Recommended with Ramp Sampling to decrease image blurring. This option is not supported with the Body coil.
Accept	**[Accept]**	Confirms the selected values and closes the User CVs Additional Parameter screen.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Scan	**[Scan]**	Initiates Auto Prescan and the *i*Drive Acquire tab opens. Home images are acquired and at this point, the Acquire tab can be used to navigate through the anatomy and alter image contrast as needed. Scan planes and slice locations can be copied from the *i*Drive windows to a series in the Rx Manager.

Perform Manual Echo Alignment for the FGRET-RT Sequence

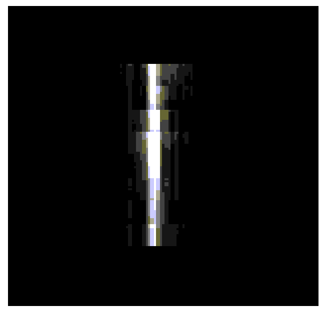
Manual echo alignment can be performed if after performing the FGRET-RT series, image quality is in question. Manual echo alignment can also be performed prior to starting the real time sequence. This process allows a manual check of the echo alignment to ensure optimum image quality. Even when this procedure is performed, image quality can be affected by phase offsets which are inherent to ET sequences. This procedure guides you through the process of manually aligning the echoes for the FGRET-RT pulse sequence.

1. Prescribe the series to be used for the FGRET-RT acquisition.
   - Refer to the FGRET-RT decision matrix.
2. Turn Real Time off.
   - Located on the Imaging Options window.
3. Click the **User CVs Screen** icon.
   - Located in the Additional Parameters area.
4. Enter **1** in the **Echo tuning mode** text box.
   - Prompts the system to display a representation of the echoes from which proper alignment can be assessed.
5. Click **[Accept]**.
   - Accepts the entry and closes the User CVs screen.
6. Click the **Graphic Rx** icon.
   - Located in the Additional Parameters area.
7. Prescribe one slice location through the center of the anatomy.
   - The slice angle, FOV, RBw, and matrix values must be exactly the same as the FGRET series.
8. Click **[Accept]**.
   - Accepts the prescription and closes the Graphic Rx screen.
9. Click **[Save Series]**.
   - Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.

Quick Steps: Perform Manual Echo Alignment for the FGRET-RT Sequence

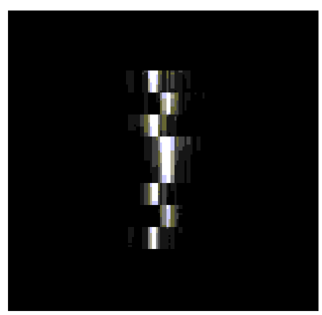
1. Prescribe the series to be used for the FGRET-RT acquisition.
2. Turn Real Time off.
3. Click the **User CVs Screen** icon.
4. Enter **1** in the **Echo tuning mode** text box.
5. Click **[Accept]**.
6. Click the **Graphic Rx** icon.
7. Prescribe one slice location through the center of the anatomy.
8. Click **[Accept]**.
9. Click **[Save Series]**.
10. Click **[Prepare to Scan]**.
11. Click **[Scan]**.
12. Evaluate the images.
13. Prescribe the FGRET-RT pulse sequence.

10. Click **[Prepare to Scan]**.
    - Downloads the series.
11. Click **[Scan]**.
    - Auto Prescan is performed and the system initiates the data acquisition with echo tuning mode on.
12. Evaluate the images.
    - If the echoes are aligned, continue with step13.



Aligned Echoes

    - If the echoes are misaligned, adjust the echo alignment using the Adjust Echo Alignment for the FGRET-RT Sequence procedure.



Misaligned Echoes

13. Prescribe the FGRET-RT pulse sequence.
    - Refer to the FGRET-RT decision matrix.
    - Set the Manual echo alignment to zero.

Adjust Echo Alignment for the FGRET-RT Sequence

Use this procedure if you have performed a manual echo alignment of the FGRET-RT pulse sequence and the echoes are misaligned. Another series must be acquired to adjust the echo alignment. This procedure guides you through the process of adjusting the echo delay to bring the echoes more closely into alignment.

1. Copy and paste the FGRET-RT series used in the Manual Echo Alignment process.
2. Click **[View Edit]**.
   - Opens the series and allows for changes.
3. Click the **User CVs Screen** icon.
   - Located in the Additional Parameters area.
   - The User CVs return to their default state when a new series is selected.
4. Enter **1** in the **Echo tuning mode** text box.
   - Prompts the system to display a representation of the echoes from which proper alignment can be assessed.
5. Enter **6** in the **Echo delay** text box.
   - Values from ±1 to ±12.
     – The delay unit is microseconds.
6. Enter **1** in **Manual echo alignment** text box.
   - Enables manual alignment.
7. Click **[Accept]**.
   - Accepts the entries and closes the User CVs screen.
8. Click **[Save Series]**.
   - Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
9. Click **[Prepare to Scan]**.
   - Downloads the series.
10. Click **[Scan]**.
    - Auto Prescan is performed and the system initiates the data acquisition with Echo tuning mode on.

Quick Steps: Adjust Echo Alignment for the FGRET-RT Sequence

1. Copy and paste the FGRET-RT series used in the Manual Echo Alignment process.
2. Click **[View Edit]**.
3. Click the **User CVs Screen** icon.
4. Enter **1** in the **Echo tuning mode** text box.
5. Enter **6** in the **Echo delay** text box.
6. Enter **1** in **Manual echo alignment** text box.
7. Click **[Accept]**.
8. Click **[Save Series]**.
9. Click **[Prepare to Scan]**.
10. Click **[Scan]**.
11. Evaluate the images.
12. Repeat the acquisition, changing the echo delay each time, until the echoes are aligned as well as possible.
13. Record the value of the optimal echo delay.
14. Prescribe the FGRET-RT pulse sequence.
15. Enter the echo values on the User CVs screen.
16. Scan the FGRET-RT pulse sequence.

11. Evaluate the images.
    - If the echoes are aligned, continue with step 13.
    - If the echoes are misaligned continue with step 12.
12. Repeat the acquisition, changing the echo delay each time, until the echoes are aligned as well as possible.
    - Continue to repeat steps 1 to 11 to adjust the echo delay value.
    - Adjust the echo delay in increments of one.
      – This may be a negative value.
13. Record the value of the optimal echo delay.
    - This value will be manually entered in a later step.

NOTE: If you are unable to align the echoes, contact your service engineer.

14. Prescribe the FGRET-RT pulse sequence.
    - Refer to the FGRET-RT decision matrix.
    - The slice locations must be the same obliquity as the location used for the manual echo alignment series.
15. Enter the echo values on the User CVs screen.
    - Echo tuning mode = 0
      – Zero is off.
    - Echo delay = the value determined in step 13.
    - Manual echo alignment = 1
      – One is on.
16. Scan the FGRET-RT pulse sequence.
    - Refer to the FGRET-RT decision matrix.

Chapter 14

Spiral Pulse Sequences

Introduction

The Spiral pulse sequence is a 2D, Gradient Echo (GRE) or Spoiled Gradient Echo (SPGR) sequence which uses a spiral trajectory to obtain the required data for image creation. There are two types of Spiral imaging available: High-Resolution (Hi-Res) Spiral and Real Time Spiral.

This chapter explains the pulsing components and timing factors directly related to the Spiral imaging pulse sequences. It contains the step-by-step instructions to help you learn how to:

- Prescribe a Hi-Res Spiral Sequence
- Prescribe a Real Time Spiral Sequence

In addition, this chapter answers the following questions:

1. What is Spiral?
2. When would I use a Spiral pulse sequence?
3. What methods can I use to acquire a Spiral pulse sequence?
4. What are the imaging characteristics of a Spiral pulse sequence?
5. Which imaging options can be used with a Spiral pulse sequence?
6. What are some applications for Spiral sequences?

What Do I Need to Know About...

This section presents the concepts necessary to understand imaging with Spiral pulse sequences. Specifically, you need to understand the following concepts:

- Spiral Basics
  - Parameter Selection Effects
  - Peripheral Nerve Stimulation
- High Resolution Spiral
  - Gated Non-Sequential Hi-Res Spiral
  - Gated Sequential Hi-Res Spiral
  - Imaging Characteristics
  - Associated Imaging Options
  - Applications
- Real Time Spiral
  - Parameter Selection Effects
  - Imaging Characteristics
  - Associated Imaging Options
  - Applications

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Spiral Basics

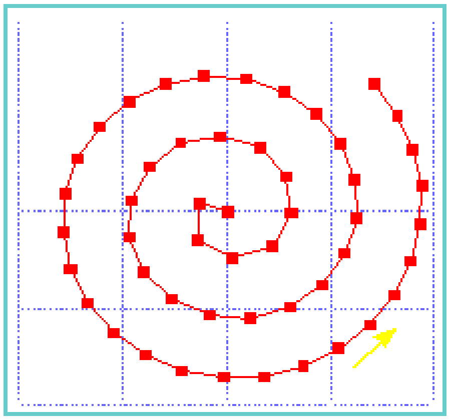
Spiral imaging is a data acquisition method in which k-space is filled in a spiral fashion, as opposed to k-space being filled in a uniform rectilinear grid. Following spiral data collection, the data is interpolated onto a rectilinear grid, which is necessary for applying the Fast Fourier Transform (FFT) for image formation.

The Spiral pulse sequence is a 2D, GRE or SPGR sequence which uses a spiral trajectory to obtain the required data for image creation. A spiral trajectory is obtained by simultaneously applying the gradients in the X and Y directions. By knowing the strength and direction of the gradients at any given time, points within the anatomy can be localized and a gradient echo can be collected.

Spiral imaging provides the following benefits:

- Efficient k-space data collection
  - Filling k-space in a spiral trajectory allows the necessary data to be collected quicker as compared to line-by-line data collection using a rectilinear grid. The outermost corners of k-space are not filled in a spiral trajectory. Figure 14-1 illustrates of a single spiral trajectory.
- Center of k-space is over-sampled
  - This is due to data collection beginning at the center of k-space. This provides an effect similar to multiple averaging of data.
- Relatively short echo times
  - This results from data collection that can begin immediately after radio frequency (RF) excitation.
- Intrinsic flow and motion compensation properties
  - These properties result in images with reduced motion artifacts without the use of flow compensation (FC) or other motion compensation techniques.

Figure 14-1 Single Spiral Trajectory or Arm. This arm contains 50 points of data.



Either a single trajectory or multiple trajectories can be performed in Spiral imaging. The number of trajectories for a sequence is defined as the "number of arms." Each arm contains a defined number of points and each point is a piece of data, which contributes to the filling of k-space. A point is the number of data points that are collected for each spiral arm. The number of arms and points, along with the selected field of view (FOV) and receive bandwidth (RBw) contribute to image resolution. The maximum number of points and arms allowed is based upon Equation 14-1.

Equation 14-1 Maximum Number of Point and Arms

# of Points x # of Arms x The Decimation Factor ≤ 131,072

The decimation factor is based on the prescribed RBw. At 125 kHz, the decimation factor is 1, at 62.5 it is 2, and at 31.25 it is 3. The system displays an error if the selected combination of points, arms, and RBw is unacceptable.

Although these parameters affect resolution, there is not a direct method of calculating resolution based only on these factors. The effective resolution is displayed in the Acquisition Timing area. Effective resolution is based on the acquired resolution and the reconstruction resolution. It is automatically calculated and displayed. Due to the interpolation of the spiral data into a rectilinear grid needed for the FFT, reconstruction times are longer, as compared to many other types of pulse sequences.

The Acquisition Timing area is modified to reflect a spiral acquisition. The **Points** text box replaces Frequency, and **Arms** text box replaces Phase. The **Effective Resolution** text box is displayed in place of the Frequency Direction (there is no frequency direction in a spiral data acquisition) and displays the effective resolution of the prescribed sequence. The **B_0 Maps** text box is seen in place of Phase Correct. Figure 14-2 displays the modified Acquisition Timing area and Table 14-1 describes the new text boxes.

Figure 14-2 Spiral Acquisition Timing Area

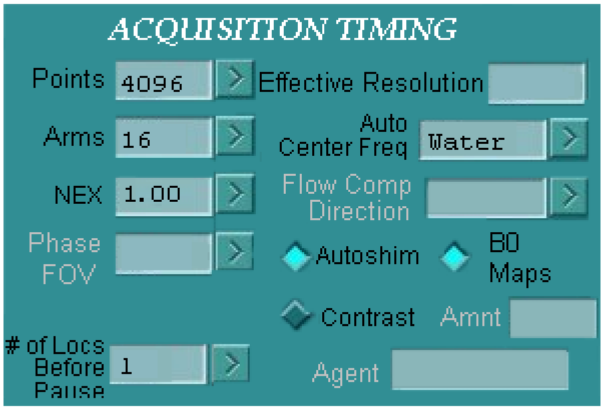


Table 14-1 Spiral Acquisition Timing Selections

Selection	Description
Points	Defines the number of data points that are collected for each spiral arm. The minimum is 512 and the maximum is 8192 (4096 for a multi-array coil), in increments of 2. Points and Arms are annotated in place of the Matrix, e.g., 4096x32/1.00NEX.
Arms	Defines the number of spiral trajectories that are performed. Multiple arms can be interleaved within the same TR, or they can be collected in consecutive TRs; the method used depends on the type of spiral sequence being performed. Increasing the number of arms increases spatial resolution because sampling is taking place further toward the edges of k-space. The minimum is 1 and the maximum is 32, in increments of 1.
Effective Resolution	Shows the effective resolution of the prescribed series in millimeters. This text box is not editable. The Effective Resolution annotation replaces the Frequency direction in the lower right corner of the image, e.g., EffR: 0.51.
B_0 Maps	Compensates for phase differences that result from inhomogeneities by performing a type of phase correction. Turning B_0 Maps on can improve image quality. Two spiral arms (TRs) are added to an acquisition when B_0 Maps is on, adding a minimal amount to scan time, thus extending breath-hold acquisition times. When B_0 Maps is used, it is indicated in the same fashion as Phase Correct. PC is annotated as a prescan option on the Series Text page.

Parameter Selection Effects

The effects of changing sequence parameters in spiral imaging may differ from other pulse sequences, or the effects may be more pronounced. Table 14-2 can be used for reference when setting up a spiral sequence. The parameters in the table are mentioned because of the importance of choosing these factors carefully for spiral imaging.

Table 14-2 Imaging Effects with Spiral Sequences

Parameters	SNR	Spatial Resolution	Scan Time	Image Blurring	Spiral Aliasing (wrap)
⇑ **RBw**	⇓	No change or slight ⇓	No change	⇓	No change
⇑ **# of Arms**	⇓	⇑	⇑	No change	No change
⇑ **# of Points**	⇓	⇑	No change or slight ⇑	⇑	No change
⇑ **FOV**	⇑	⇓	No change	⇑	⇓
Center Freq off-center	⇓	No change	No change	⇑	No change

There are several additional factors that affect image contrast:

- Applying a 60° flip angle allows you to maintain a T1 weighted contrast on static tissue, allowing bright flow signal.
- The T2 Prep Imaging Option is a magnetization prep pulse that allows suppression of muscles and venous structures.

There are several factors you should consider when using Spiral sequences:

- Wrap-around (aliasing) can occur in all directions in spiral acquisitions, except in the slice-select direction. Use FOVs large enough to cover the anatomy of interest to avoid this wrap.
- Incorrect coil positioning can result in stimulation of tissue outside the FOV, which results in increased aliasing; therefore, it is important to ensure correct coil positioning over the anatomy of interest.
  - It may be beneficial to use a decreased number of coil elements, when possible, to help decrease the possibility of aliasing from unwanted tissue. For example, the Cardiac Phased Array coil allows selection of either the anterior or posterior coil elements by selecting CARDIAC_ANT or CARDIAC _POST respectively. Turning off un-needed coil elements decreases the possibility of aliasing from unwanted anatomy.

Peripheral Nerve Stimulation

Spiral imaging increases the possibility of Peripheral Nerve Stimulation (PNS). dB/dt refers to the rate of change in magnetic field to time, which is expressed in Tesla/seconds. dB/dt and specific absorption rate (SAR) levels for the patients are based on current scientific literature related to safety, and that the level of exposure shall be a medical judgment as to the patient's potential risk versus benefit.

PNS is described as a light touching sensation felt on various areas of the skin surface. These areas vary, depending upon which gradient axis is in use. Some common areas for the sensation are the bridge of the nose, arms, chest and upper abdomen. Hands clasped together considerably lowers nerve stimulation thresholds and should be avoided. The potential for PNS is low, but it exists for all sequences and gradient configurations.

CAUTION: **Patients who complain of PNS during a Spiral sequence should have the series stopped and replaced with another pulse sequence. If the PNS occurs with a non-Spiral sequence, the patient should be removed from the magnet and the incident reported to GE Medical Systems.**

PNS is not harmful. The potential for inducing PNS is kept within limitations. In the United States, the system is limited from operating above 66% of the PNS threshold by the software (unless the system is operating in research mode). The point at which 50% of a population will experience PNS is the PNS threshold.

Your MR system is capable of operating under two modes: Clinical mode (normal) and Research mode (proprietary license agreement with GE).

High Resolution Spiral

High Resolution Spiral (Hi-Res Spiral) has been developed to obtain high resolution images in ultra-fast scan times, in seconds and even milliseconds. This sequence is well suited for obtaining images of the coronary arteries.

Hi-Res Spiral acquisitions can be performed in cardiac-gated or non-gated method. To perform a spiral sequence, either Spiral Gradient Echo (GRE) or Spiral Spoiled Gradient Echo (SPGR) is selected on the Pulse Sequence window. Selections on the Imaging Options window further define the type of data to be acquired.

Hi-Res Spiral sequences can be acquired cardiac-gated or non-gated.

- Non-gated Hi-Res Spiral is a 2D, GRE or SPGR sequence.
  - Spiral GRE or Spiral SPGR is selected on the Pulse Sequence window.
  - One or more slice locations can be acquired.
  - Non-gated Hi-Res Spiral is not commonly used due to the nature of the anatomy.
- Gated Hi-Res Spiral is a 2D, GRE or SPGR sequence that is cardiac-gated in the same manner as a FastCard sequence.
  - Two types of gated spiral can be performed: non-sequential and sequential.

Gated Non-Sequential Hi-Res Spiral

In a Gated Non-Sequential Hi-Res Spiral sequence, single-slice or multi-slice imaging is allowed. In multi-slice, the maximum number of slices allowed is based on the heart rate. Only a single cardiac phase can be acquired.

There are three types of Gated Non-Sequential Hi-Res Spiral sequences:

- Single-arm, single-slice acquisition
  - Obtains all the data for the slice in one TR, also called a single-shot. This sequence is rarely performed due to poor image resolution.
- Single-arm, multi-slice acquisition
  - Obtains all the data for all locations in a single R-R interval. Each slice location is acquired in a single shot. This sequence is rarely performed due to poor image resolution.
- Multi-arm acquisition
  - Repeats the data acquisition, which took place in the single-arm acquisition, whether it is single or multi-slice. All slice locations are acquired at the same phase of the cardiac cycle.

Gated Sequential Hi-Res Spiral

Gated Sequential Hi-Res Spiral sequences can acquire single-slice or multi-slice images. Sequential must be selected on the Imaging Options window to perform this sequence. The sequence then allows you to acquire multiple cardiac phases. The number of cardiac phases obtained can be entered manually in the **# of Cardiac Phases to Reconstruct** text box on the Cardiac Gating/Triggering screen. Alternatively, the number of phases acquired can be automatically determined by the system when Auto is selected for the number of cardiac phases to reconstruct.

There are four types of Gated Sequential Hi-Res Spiral sequences.

- Single-arm, single-slice acquisition
  - Obtains all the data for one phase in one TR period, then repeats the data acquisition at subsequent phases within one cardiac cycle.
- Multi-arm, single-slice acquisition
  - Repeats the single-arm sequence to complete the number of arms defined; if six arms are prescribed, the sequence is repeated six times.
- Single-arm, multi-slice acquisition
  - Obtains all the phase data for a single location in one R-R interval. All phases for the next location are obtained in the next R-R interval, and so on, until all slices are complete.
- Multi-arm, multi-slice acquisition
  - Completes all the arms for slice one, collecting all phases for that slice in one R-R interval. All phases and arms are then collected for the next slice, and so on, until all slices are complete.

For multi-slice acquisitions, if a negative spacing (overlap) is prescribed, the slice locations are acquired in an interleaved fashion to avoid cross-talk. Otherwise, acquisition slice ordering is done sequentially. Reducing the flip angle from 60° to 45° for gated sequential acquisitions reduces saturation effects and improves SNR.

In gated sequences, extend the trigger delay (TD) to a point at which mid-diastole is taking place (commonly 350 to 450 ms) to obtain images during the most quiescent part of the cardiac cycle. Another benefit of obtaining image data at mid-diastole is flow is maximized at this time.

Imaging Characteristics

Spiral imaging produces images with high spatial and temporal resolution. The pulse sequences are annotated “GR/SPIRAL/20” or “SPGR/SPIRAL/20” with 20 indicating the flip angle.

Figure 14-3 Hi-Res Spiral Image of the Coronary Artery

Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 14-3, the X’s indicate the imaging options available for use with the Hi-Res Spiral pulse sequence.

Table 14-3 Hi-Res Spiral Pulse Sequence Imaging Options

Imaging Options			
	None	**X**	Variable Bandwidth
X	Flow Compensation		No Phase Wrap
	POMP	**X**	Extended Dynamic Range
	Square Pixel		Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer	**X**	Sequential
X	Cardiac Gating/Triggering		Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024		ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station		Real Time
X	T2 Prep	**X**	Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

Two primary imaging options are available for Spiral imaging.

- Spectral Spatial RF (SSRF) uses slice-selective pulses to suppress signal from fat.
  - This can be especially useful for suppressing the fat that may interfere with visualization of the coronary arteries.
- T2 Prep applies a sequence of non-selective 90° and 180° RF pulses to suppress tissue.
  - This can be used to decrease signal from surrounding venous structures and lessen signal from tissue such as cardiac muscle.

There are several factors you should consider when using the imaging options with Hi-Res Spiral sequences:

- When FC is used, it is applied in the slice-select direction only.
- Sequential can only be used in the gated mode and is required for multiple cardiac phases.
- The RBw is limited to 31.25, 41.67, 62.5, and 125 kHz.
  - When the number of points is prescribed to 2048 or greater, the RBw must be set to 125 kHz.

In addition, Hi-Res Spiral is also compatible with the following options:

- Phased array
- Fat and water suppression
  - Not allowed with SSRF
- Spatial SAT
  - Not allowed with T2 Prep

Applications

Spiral imaging is intended for whole body imaging and is capable of producing images with high spatial and temporal resolution, such as fine structures where motion can be a problem. Examples include:

- Cardiac Gated Hi-Res Spiral can be used to image the coronary arteries.
- Single-slice, Multi-phase Cardiac Gated Hi-Res Spiral can be used to capture in plane, multiple cardiac phases of a single coronary artery.
- Visualization of the coronaries may be improved with the use of SSRF.
- T2 Prep can be used to decrease signal from venous structures.

WARNING: The system cardiac gating waveforms are not to be used for physiologic monitoring. The patient's condition may not be reflected, resulting in improper emergency medical treatment.

Real Time Spiral Imaging

Real Time Spiral Imaging is used with the *i*Drive Pro Plus Real Time Cardiac Acquisition (RTCA) imaging feature. Real Time Spiral acquisitions are defined by selecting either Spiral GRE or Spiral SPGR on the Pulse Sequence window and Real Time on the Imaging Options window. As in any *i*Drive RTCA prescription, only one location is prescribed for this sequence.

The following are key components of Real Time Spiral:

- All coil types are allowed.
- Cardiac Gating/Triggering is not allowed.
  - The Real Time Spiral frame-rate is typically described in frames per second (FPS) providing high-temporal resolution images exhibiting little or no motion in areas such as the heart.
- Real Time Spiral images are of low spatial resolution, so this sequence is typically used for localization of anatomy.
- The prescribed number of points affects the maximum number of arms allowed. Likewise, the number of arms affects the maximum number of points allowed.
- The Imaging Option SSRF is available with Real Time Spiral.
  - SSRF can be used to suppress signal from fat. This can be especially useful for suppressing the fat that may interfere with visualization of the coronary arteries.

NOTE: Refer to the Imaging with Real Time chapter in this guide for additional information on *i*Drive Pro Plus.

Parameter Selection Effects

Real Time Spiral is compatible with the following selections.

- Phased array
- RBw limited to 62.5 and 125 kHz
- Fat suppression
- B_0 Maps

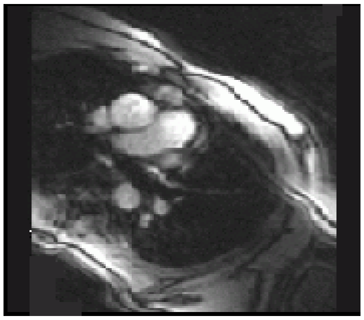
In addition, there are several factors you should consider when using Real Time Spiral:

- If B_0 Maps is desired, it must be turned on in the Acquisition Timing area during series prescription and cannot be turned on/off at the *i*Drive Pro Plus Acquire tab.
  - B_0 Maps is annotated on the Series Text page as PC.
- When B_0 Maps is turned on during series prescription, the displayed FPS value is indicative of the frame rate during the point in data acquisition when the B_0 Map function is performed.
  - The actual frame rate (when B_0 Maps is not being performed) is likely to be higher.
- If the effective resolution (which is based on the points, arms and RBw) is below the value resulting from the FOV (in mm) divided by 128, the system requires a change in either points, arms, or RBw.
- If the FOV (in mm) divided by 128 is greater than the calculated effective resolution, the resulting image resolution is based on the equation, not the effective resolution.
  - FOV (in mm) divided by 128 = Pixel size
- Fat suppression must be turned on during series prescription and cannot be turned on/off at the *i*Drive Pro Plus Acquire tab.
- Spatial SAT pulses are not allowed.

Imaging Characteristics

Real Time Spiral is a low spatial resolution sequence. The pulse sequence is annotated “GR/SPIRAL/20” or “SPGR/SPIRAL/20” with 20 indicating the flip angle. The images are not annotated to show that Real Time was selected on the Imaging Options window.

Figure 14-4 Real Time Spiral Image



Associated Imaging Options

Imaging Options provide image processing or filters for enhancing anatomical features or reducing noise. In Table 14-4, the X's indicate the imaging options available for use with the Real Time Spiral pulse sequence.

Table 14-4 Real Time Spiral Pulse Sequence Imaging Options

Imaging Options			
	None	**X**	Variable Bandwidth
	Flow Compensation		No Phase Wrap
	POMP	**X**	Extended Dynamic Range
	Square Pixel		Surface Coil Intensity Correction
	Respiratory Compensation		Classic
	Magnetization Transfer		Sequential
	Cardiac Gating/Triggering		Respiratory Gating/Triggering
	Tailored RF		IR Prepared
	DE Prepared		Multi-Phase
	Full Echo Train		CCOMP
	ZIP 1024		ZIP 512
	Zip x 2		ZIP x 4
	SmartPrep		Blood Suppression
	Multi Station	**X***	Real Time
	T2 Prep	**X****	Spectral Spatial RF
	Phase Sensitive		Navigator
	ASSET Calibration		Fluoro Trigger
			ASSET

NOTE: *Real Time must be selected to acquire Real Time Spiral images.

NOTE: **SSRF must be turned on during series prescription on the Imaging Options window and cannot be turned on/off at the *i*Drive Pro Plus Acquire tab.

Applications

Real Time Spiral can be used for the quick localization of anatomy lying in double-oblique planes and in areas where motion can be a problem, such as the coronary arteries.

How Do I...

This section provides the step-by-step instructions for prescribing Spiral imaging pulse sequences. Specifically, it describes how to:

- Prescribe a Hi-Res Spiral Sequence
- Prescribe a Real Time Spiral Sequence

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the “What You Select” column of the matrix uses two other conventions.

- N/A indicates that the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates that the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

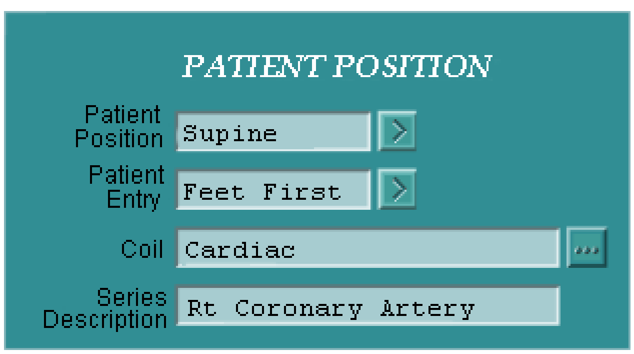
CAUTION: Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.

Prescribe a Hi-Res Spiral Sequence

The Hi-Res Spiral sequence is useful in clinical applications to obtain high-resolution images in ultra-fast scan times. This sequence is well suited for acquiring images of the coronary arteries. Visualization of the coronaries may be improved with the use of T2 Prep and SSRF.

The decision matrix (Table 14-5) is only for prescribing a Hi-Res Spiral scan with cardiac gating. The following example protocol is for prescribing an oblique right coronary artery cardiac scan for a TwinSpeed or an EchoSpeed system.

Table 14-5 Hi-Res Spiral Protocol Example (Right Coronary Artery)

Hi-Res Spiral Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Scan Rx	Acquire a localizer series	Allows Graphic Rx to become available so you can prescribe slices graphically on the localized image.
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol screen becomes active.
Patient Position		
		
Patient Position	**Supine**	Indicates the orientation of the patient. Although compatible with any patient position and entry, supine and feet first are recommended. This ensures accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	

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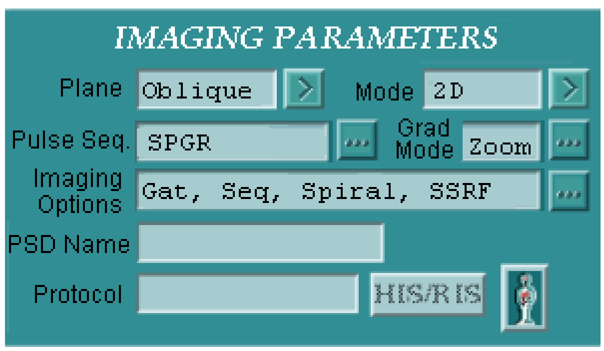
Hi-Res Spiral Protocol Example

What You Select		Selection Notes
Coil	**Phased Array > Cardiac**	Allows selection of the coil from which the signal is transmitted and received. Use a coil that produces the optimum coverage and SNR. Up to a four-coil phased array coil is allowed. Note that two additional configurations are available for the Cardiac PA coil. CARDIAC_ANT and CARDIAC_POST turn on the two coil elements in the anterior and posterior portion of the cardiac coil, respectively. CARDIAC_ANT can be used to reduce signal from posterior anatomy, thus reducing the potential for aliasing from the spine and back in spiral acquisitions. These selections are available from the Phased Array coil list.
Series Description	Enter a series description in the text box.	Allows you to enter a brief description of the series being prescribed. If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

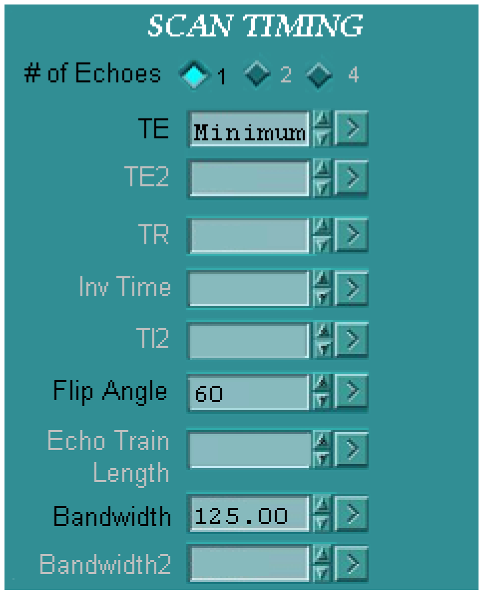
Imaging Parameters



Plane	**Oblique**	Defines the scan plane of the acquisition. Compatible with any scan plane. Select the plane that best meets your clinical need. Oblique is generally used to obtain the proper angle through the heart.
Mode	**2D**	Prescribes a two-dimensional sequence.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Sequence	**Spiral SPGR**	Prescribes a Spiral SPGR pulse sequence. Spiral GRE is also an allowable selection.
Imaging Options	**Cardiac Gating Triggering**, **Sequential**, and **Spectral Spatial RF**	Provides appropriate options for enhancing anatomical features and reducing noise. Cardiac Gating/Triggering and Sequential allow a gated sequence with multiple cardiac phases. Select Sequential for a single cardiac phase acquisition and do not select for a multiple phase cardiac acquisition. This sequence can also be acquired without cardiac gating. SSRF can be used to suppress signal from fat that may interfere with visualization of the coronary arteries. Select T2 Prep to diminish signal from tissue such as muscle and venous structures. Use of T2 Prep dramatically reduces SNR.

Hi-Res Spiral Protocol Example		
What You Select		**Selection Notes**
PSD Name	N/A	
Protocol	N/A	

Scan Timing



# of echoes	N/S	One echo is selected automatically.
TE	**Minimum**	The only TE available selection is minimum.
TE2	N/A	
TR	N/S	The minimum TR is used to maintain ultra-fast scan times.
Inv Time	N/A	
TI2	N/A	
Flip Angle	**60**	The typical flip angle value is 60°. Decrease the flip angle to 45° for sequential acquisitions to reduce saturation effects.
Echo Train Length	N/A	
Bandwidth	**125.00**	The RBw values allowed are 31.25, 41.67, 62.5, and 125 kHz. Typical values are 62.5 and 125 kHz. The systems selects one of the four values closest to the typed-in value. Increasing the RBw results in decreased SNR, decreased image blurring, and a slight decrease in spatial resolution. The bandwidth must be set to 125 kHz when the number of points is 2048 or greater.
Bandwidth2	N/A	

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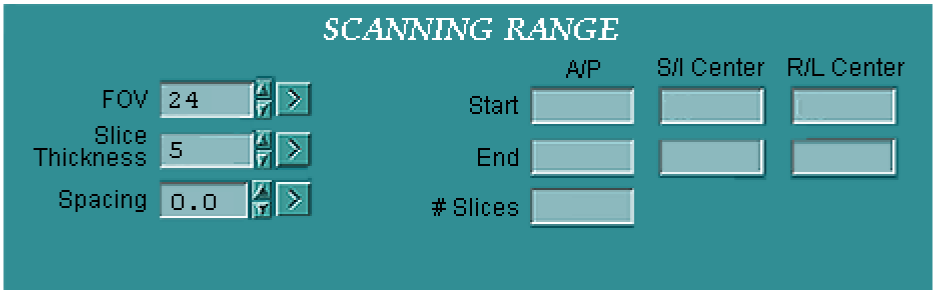
Hi-Res Spiral Protocol Example

What You Select		Selection Notes
Scanning Range		

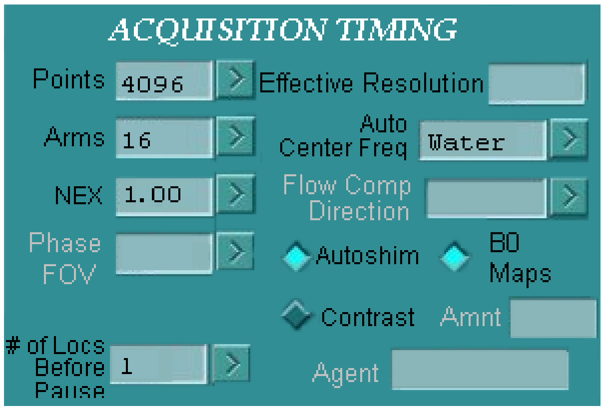


FOV	**24**	Defines the size of the area imaged. Select an FOV that covers the anatomy of interest, about 20 to 40 cm. Anatomy outside the FOV results in spiral aliasing. As the FOV decreases, SNR decreases, spatial resolution increases, and image blurring decreases.
Slice Thickness	**5**	Defines the thickness of the image slice. A slice thickness of 3 to 5 mm is generally used. As the slice thickness decreases, SNR decreases.
Spacing	Enter **`0.0`** in the text box.	Places a zero spacing between the prescribed slice locations. Zero spacing or even a negative spacing is commonly used. A negative spacing, e.g., -2.5, is allowable, up to 50% of the slice thickness. When a negative spacing is prescribed, slice-ordering is performed in an interleaved fashion to minimize cross-talk. Note that cardiac vessels may be more successfully captured with sequential slice ordering.
Start, End Locations		Determines the start and end locations from the Graphic Rx program after the slices are prescribed and posts the locations here.
# Slices		Determines the number of slices as prescribed in Graphic Rx and posts it here. Adjust the number of slice locations as necessary.

Hi-Res Spiral Protocol Example

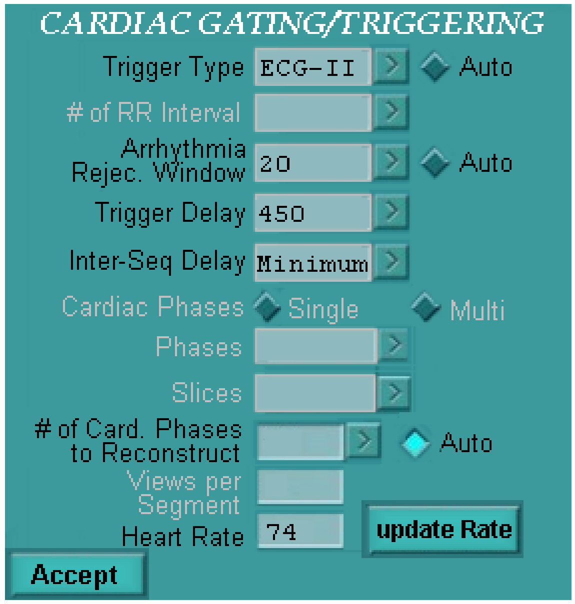
What You Select		Selection Notes

Acquisition Timing

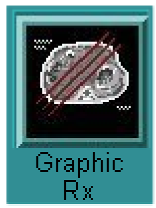


Points	**4096**	Defines the number of data points to be collected for each spiral arm. The typical values are 2048 to 4096 points. As the number of points increases, spatial resolution increases as indicated by the smaller effective resolution. As pixel size gets smaller, SNR decreases as indicated by the SNR meter. The prescribed number of arms and RBw affect the maximum number of points allowed.
Arms	**16**	Defines the number of spiral trajectories to be performed. The typical values are 16 to 24 arms. Increasing the arms and the RBw affect the maximum number of arms allowed.
NEX	**1**	Low NEX values are generally used to maintain ultra-fast scan times. As NEX increases, SNR and scan time increase.
Phase FOV	N/A	
Effective Resolution	N/S	Calculates the effective resolution by the system and posts it here in millimeters. This text box is non-editable. Effective resolution is displayed when the FOV, arms, points, and RBw are defined.
Auto Center Freq	**Water**	Sets this CF peak during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Improves image quality and is recommended for this sequence.
B_0 Maps	**On**	Improves image quality and corrects for phase differences that result from field inhomogeneities. The use of B_0 Maps adds to the total scan time, but is recommended.
# of Locs Before Pause	**1**	Allows for breath-hold acquisitions. If acquiring the slices sequentially, use one location per breath-hold.

Hi-Res Spiral Protocol Example		
What You Select		Selection Notes
Additional Parameters - Gating/Triggering		



Trigger Type	Select the best lead.	Defines which signal is sent by the cardiac monitor to activate the data acquisition. When ECG gating, select the lead that provides the best signal. Peripheral gating is not recommended.
# of R-R Interval	N/A	
Arrhythmia Rejec. Window	**20**	Defines the window size, as a percentage of the R-R interval, outside of which the system rejects data if a trigger is detected. Values around 20% are most commonly used to allow reasonable latitude. If the patient's heart rate is irregular, increase this value and the TW, then the time available to collect the data will decrease.
Trigger Delay	Enter **450** in the text box.	Defines the delay time between the occurrence of the triggering pulse and the actual onset of imaging. Values between 350 and 450 are most common. In addition to manually entering a value, the minimum and recommended choices can also be selected. Increasing the TD decreases the maximum number of slices allowed.
Inter-Seq Delay	**Minimum**	Defines the time between each image in the cardiac cycle. Minimum or Even spacing are the choices.
Cardiac Phases	N/A	
# of Card. Phases to Reconstruct	**Auto**	Collects the maximum number of phases available automatically. The number of cardiac phases can also be entered manually in the text box.
Views per Segment	N/A	

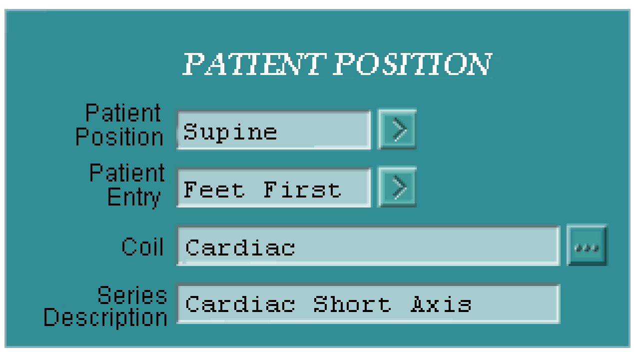
Hi-Res Spiral Protocol Example		
What You Select		**Selection Notes**
Heart Rate	**[update Rate]**	Lets the system obtain an automatic reading of the current heart rate. Updates the rate prior to beginning the scan.
Accept	**[Accept]**	Confirms the selected values and closes the Gating/Triggering Additional Parameter screen.
Additional Parameters - Graphic Rx		
		
[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.
Image Viewport	Click the image to display the line cursor.	Prescribes slices for graphic prescription. Select the adjustment handles to angle, draw, and remove slices. Position the slices to cover anatomy of interest and view the Advisory Panel to note the maximum number of slices per acquisition and the number of acquisitions you are prescribing. The scan time increases as the number of acquisitions increase.
Copy Rx	**[Copy Rx]** (optional)	Copies the exact locations of the prior series if you had previously graphically prescribed a series with the same plane, FOV, and slice thickness.
Erase All	**[Erase All]** (If necessary)	Eliminates the graphic prescription from the screen and allows you to start over.
Reset Center	**[Reset Center]** (If necessary)	Re-establishes the FOV center on a different localized slice.
Accept	**[Accept]**	Confirms the cursor position and closes Graphic Rx.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition. Select for breath-hold acquisitions.
Scan	**[Scan]**	Initiates the acquisition. Instruct the patient to hold his/her breath as long as possible, until the scan stops, if able.

Prescribe a Real Time Spiral Sequence

The Real Time Spiral sequence is performed using *i*Drive Pro Plus to obtain real time image data with interactive scan plane manipulation. This is useful to quickly obtain localizer images and locations for imaging cardiac anatomy, as well as, other areas of the body.

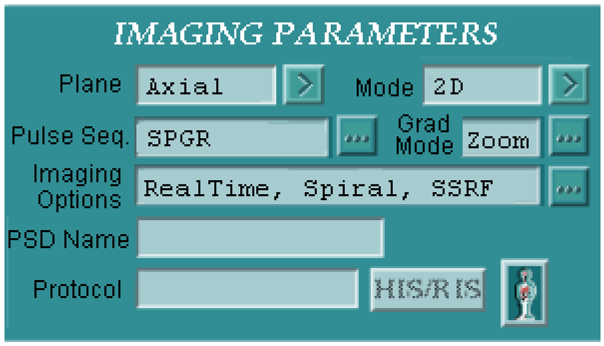
The decision matrix (Table 14-6) is only for prescribing a Real Time Spiral scan. The following example protocol is for prescribing an oblique short axis cardiac scan for a TwinSpeed or an EchoSpeed system.

Table 14-6 Real Time Spiral Protocol Example (Short Axis Cardiac)

Real Time Spiral Protocol Example		
What You Select		**Selection Notes**
Rx Manager		
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series if the Patient Protocol screen becomes active.
Patient Position		
		
Patient Position	**Supine**	Although compatible with any patient position and entry, supine and feet first are recommended. This ensures accurate cardiac gating/triggering and patient safety by ensuring proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the dog-house.
Patient Entry	**Feet First**	
Coil	**Phased Array > Cardiac**	Use a coil that produces the optimum coverage and SNR. Up to a four-coil phased array coil is allowed. As the number of coils increases, the frame rate decreases.
Series Description	Enter a series description in the text box.	If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

Real Time Spiral Protocol Example

What You Select		Selection Notes
Imaging Parameters		



Plane	**Axial**	Only orthogonal planes are allowed during series prescription. Any plane can be obtained from the Pro Plus Acquire tab.
Mode	**2D**	Prescribes a two-dimensional sequence. 2D is the only mode allowed.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has Twin gradients.
Pulse Sequence	**Spiral SPGR**	Prescribes a Spiral SPGR pulse sequence. Spiral GRE is also an allowable selection for Real Time Spiral.
Imaging Options	**Real Time**, **Spectral Spatial RF**	Real Time enables Real Time Spiral. SSRF eliminates signal from fat. SSRF decreases the frame rate.
PSD Name	N/A	
Protocol	N/A	

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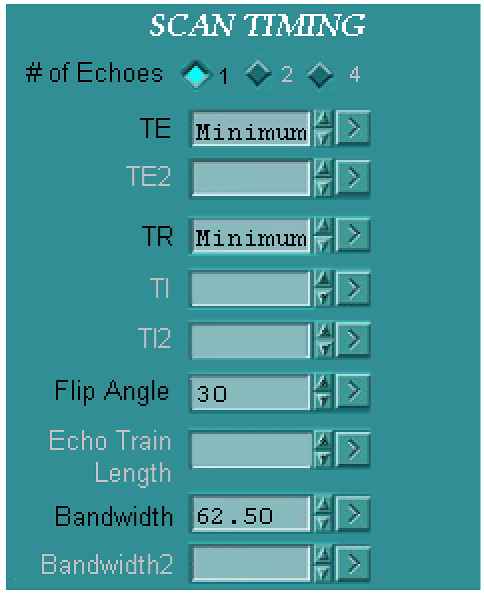
Real Time Spiral Protocol Example

What You Select		Selection Notes

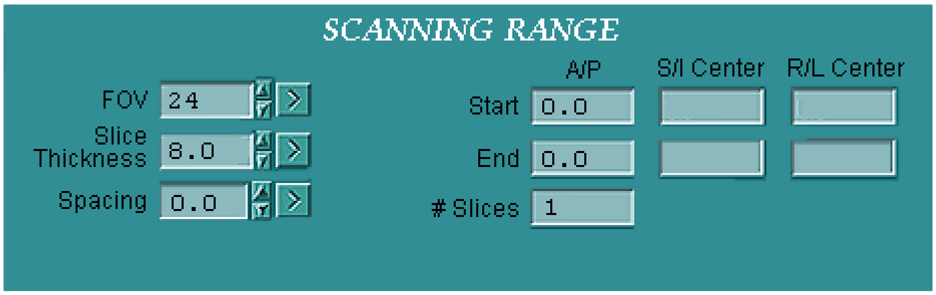
Scan Timing



# of echoes	N/S	One echo is selected automatically.
TE	**Minimum**	The only TE selection available is minimum.
TE2	N/A	
TR	**Minimum**	The minimum TR is recommended to maintain ultra-fast scan times. Selections available include minimum, 70, 80, 90, and 100.
TI	N/A	
TI2	N/A	
Flip Angle	**30**	The typical flip angle value is between 25° and 30°. Large flip angles are likely to result in tissue saturation.
Echo Train Length	N/A	
Bandwidth	**62.50**	As the RBw increases, SNR decreases, spatial resolution decreases slightly, and image blurring decreases as a result of shorter echo spaces. 62.5 and 125 kHz are allowed.
Bandwidth2	N/A	

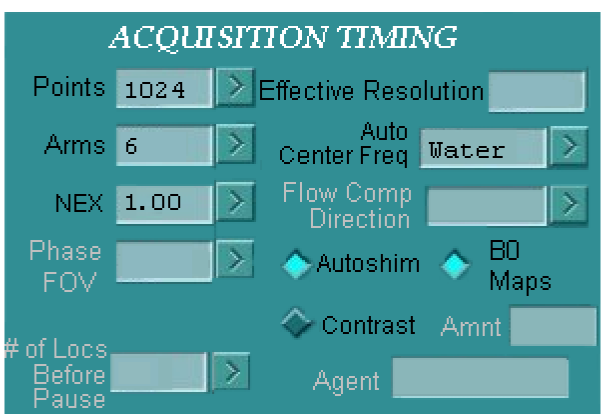
Real Time Spiral Protocol Example		
What You Select		**Selection Notes**

Scanning Range



FOV	**24**	Defines the size of the area imaged. Select an FOV that covers the anatomy of interest, about 24 to 32 cm. Anatomy outside the FOV may result in spiral aliasing. Small FOVs produce increased resolution, decreased SNR, and may decrease image blurring. Large FOVs may decrease the minimum TR and thus increase frame rate.
Slice Thickness	Enter **8.0** in the text box.	Defines the thickness of the image slice. A value of 5 to 8 mm is typically used.
Spacing	Enter **0.0** in the text box.	A single slice is prescribed for the real time series. Spacing can be zero.
Start, End Locations	Enter **0.0** in the text boxes.	Prescribes a single slice location prescription explicitly. Graphic Rx can also be used to prescribe the slice location.
# Slices	**1**	Only one slice location is allowed for real time sequences.

Acquisition Timing



Points	**1024**	Defines the number of data points to be collected for each spiral arm. As the number of points increases, spatial resolution increases as indicated by the smaller effective resolution. As the pixel size gets smaller, the SNR decreases as indicated by the SNR meter. FPS decreases.

Real Time Spiral Protocol Example		
What You Select		**Selection Notes**
Arms	**6**	Defines the number of spatial trajectories to be performed. Increasing the arms results in increased SNR, increased scan time, and increased spatial resolution, but the FPS decreases.
NEX	**1**	One NEX is generally used to maintain ultra-fast scan times. As NEX increases, SNR, and scan time increase.
Phase FOV	N/A	
Effective Resolution	N/S	Calculates the resolution and posts it here in millimeters. The Effective Resolution is a non-editable text box. Effective resolution is displayed when the FOV, arms, points, and RBw are defined.
Auto Center Freq	**Water**	Sets this CF peak during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Improves image quality and is recommended for this sequence.
B_0 Maps	**On**	Improves image quality. With B_0 Maps on, the displayed FPS is the frame rate when B_0 Maps is being performed. The actual frame rate is likely to be greater than the displayed value.
# of Locs Before Pause	N/A	
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Scan	**[Scan]**	Initiates Auto Prescan and the *i*Drive Acquire tab opens. Home images are acquired and at this point, the Acquire tab can be used to navigate through the anatomy and alter image contrast as needed. Scan planes and slice locations can be copied from the *i*Drive window to a series in the Rx Manager.

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Chapter 15

Cardiac Navigator

Introduction

Cardiac Navigator is an optional software package that enables you to perform a navigated, free-breathing, coronary artery imaging acquisition. This technique is useful in clinical applications with patients who are unable to hold their breath. The Cardiac Navigator sequence uses a 3D Enhanced Fast Gradient Echo (GRE) pulse sequence with the Navigator imaging option to acquire images.

This chapter explains the Cardiac Navigator imaging option and the method of acquiring a coronary artery data set using this acquisition technique. It contains the step-by-step instructions to help you learn how to:

- Prescribe a Cardiac Navigator Sequence
- Prescribe Localizer Images with iDrive Pro Plus
- Prescribe the Navigator Tracker
- Monitor the Navigator Pulse

In addition, this chapter answers the following questions:

1. What is Cardiac Navigator?
2. Which pulse sequence can I use with the Cardiac Navigator option?
3. Which options are compatible with Cardiac Navigator?
4. When would I use the Cardiac Navigator option?
5. What are the imaging characteristics of a Cardiac Navigator sequence?
6. What are the applications for Cardiac Navigator sequences?

What Do I Need to Know About...

This section presents the concepts necessary to understand imaging with the Cardiac Navigator imaging option. Specifically, you need to understand the following concepts:

- Background
- Cardiac Navigator Basics
  - Supported Features
- Acquiring Cardiac Navigator Sequences
  - Navigator Tracker
  - Navigator Monitor Window
- Image Characteristics
- Applications

Background

Magnetic Resonance (MR) Cardiac imaging is challenged by cardiac and respiratory motion. The heart executes a complex torquing motion as it contracts and expands during the cardiac cycle. Additionally, it moves in all three dimensions as the diaphragmatic cage moves up and down during the respiratory cycle. The motion results in ghosting and blurring artifacts, which pose a substantial challenge in coronary artery visualization and subsequent diagnosis.

With the advent of faster hardware, electrocardiogram (ECG) gating, and K-space segmenting, Fast GRE sequences have enabled the division of K-space into segments and its acquisition in successive cardiac cycles, thereby effectively "freezing" cardiac motion. Typically, these are two-dimensional (2D) sequences and are within the realm of breath-holding, in order to reduce respiratory motion artifacts.

Coronary artery imaging involves imaging of tortuous vessels with diameters ranging from 2 to 4 mm. This imposes an even higher spatial resolution limit on the imaging sequences. Three-dimensional (3D) imaging sequences are advantageous, as they allow high-resolution data sets that permit reformatting of the slices post acquisition. This can help visualize the length of tortuous vessels, which may be missed with a conventional 2D technique. 3D imaging times, however, are in the order of minutes, which rule out breath-holding as a viable option. Early sequences used respiratory bellows to track and gate to the motion of the diaphragm. This technique is sub-optimal as the abdominal motion is not necessarily representative of the diaphragmatic motion, especially in the instance where someone is a "chest breather." The technique of choice is to use navigator echoes to directly estimate the position of the right hemi-diaphragm and gate the acquisition based on this. A Fast GRE sequence with perpendicularly intersecting slab planes is used to excite a column of spins. Fourier transform of the resultant echo yields the position of the liver-lung edge, enabling prospective gating from the diaphragm position.

In prospective gating, the current position of the right hemi-diaphragm (as collected from the phase of the current navigator echo in relation to a tracker reference) is compared against the threshold as deduced from a histogram of the diaphragm displacement data over a period of time. If the position is within a narrow acceptance window about the threshold, the acquired data from the main sequence (3D Fast GRE) following the navigator sequence is accepted. The acceptance window size is fixed to an optimal value to provide a trade-off between the total scan time and the suppression of motion artifacts. Reducing the window size generally results in better image quality. However, if the window size is reduced too far, image degradation may result, directly as a product of increased scan times and changes in the respiratory cycle. Based on the total scan time, it is likely the respiratory waveform may undergo a shift in its baseline. If this occurs, the scan may not complete in an acceptable time, unless the acceptance window is widened and/or the threshold is shifted accordingly. The Navigator option allows you to manually adjust the acceptance window and/or the threshold value during the scan acquisition.

Cardiac Navigator Basics

The Cardiac Navigator feature is a purchasable imaging option that is compatible with the 3D Fast GRE pulse sequence.

This acquisition method involves acquiring a cardiac gated, 3D Fast GRE volume that covers the coronary vessels. Additionally, this volume is scanned in conjunction with a navigator pulse that tracks the motion of the diaphragm. By placing the navigator tracker pulse over the right hemi-diaphragm, the acquisition is synchronized to the end-expiration respiratory phase of the patient, thus minimizing respiratory ghosting artifacts.

The navigator acquisition interrogates the position of the right hemi-diaphragm at each R-R interval immediately prior to the data acquisition segment. If the position of the right hemi-diaphragm is within the acceptance window of the end-expiration position, then data acquisition is enabled for that R-R interval. Otherwise, the segment repeats until an acceptable diaphragm position is found. The respiratory waveform may be viewed during the acquisition to track the patient respiration and monitor whether it falls within the acquisition acceptance window and threshold level.

This application allows for improved visualization of the coronary arteries, through the following capabilities:

- A high SNR yield
- Contiguous slices
- Reformation of a single slab
- Can provide higher in-plane spatial resolution of coronary vessels, than existing, conventional, 2D breath-hold techniques
- Greater flexibility in capturing the path of the coronary vessel with the 3D volume of data, allowing an increased tolerance for slice positioning inaccuracies

Supported Features

The Navigator option is available only in the cardiac gated mode and is compatible with all the features supported by the non-navigator version of Fast GRE, except for spatial saturation and the Smart Prep options. In addition, it supports the T2 Prep imaging option to suppress the myocardial signal, while improving the contrast in the coronary arteries.

Table 15-1 lists the compatible features supported in the 3D Fast GRE pulse sequence with Cardiac Navigator option.

Table 15-1 Fast GRE with Cardiac Navigator Compatibility

Compatible	Not Compatible
Flow Compensation	Spatial Saturation
Square Pixels	POMP
Cardiac Gating/Triggering	Respiratory Compensation
DE Prepared	Magnetization Transfer
ZIP x2 and ZIP x4	Tailored RF
ZIP 512 and 1024	Full Echo Train
Variable Bandwidth	SmartPrep
No Phase Wrap	Multi Station
Extended Dynamic Range	Classic
Sequential	Respiratory Gating/Triggering
Multi Phase	IR Prepared
Cardiac Compensation	Blood Suppression

Compatible	Not Compatible
T2 Prep	Real Time
Fractional echo	Spectral Spatial RF
Fractional NEX	Fat/Water Suppression
PFOV (0.5, 0.6, 0.7, 0.8, 0.9)	
SPECIAL	
Double Oblique Scan Planes	
Reverse Loop Order	

Acquiring Cardiac Navigator Sequences

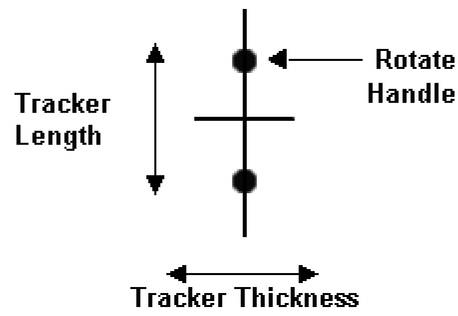
You can acquire a Cardiac Navigator sequence by prescribing a 3D Fast GRE pulse sequence and selecting the gating and navigator options from the Imaging Options window. During graphic prescription of your 3D volume, you are required to prescribe your Navigator Tracker over the right hemi-diaphragm to synchronize the acquisition to the end-expiration respiratory phase of your patient.

Navigator Tracker

You are able to prescribe the Navigator tracker on a localizer image during graphic prescription. The default length of the Navigator tracker is 100 mm with a default thickness of 20 mm. The width essentially determines the slice thickness (or diameter of the cylindrical pulse) of the excitation. These parameters are selectable and you are able to adjust them using the graphical objects of the tracker on the localizer image.

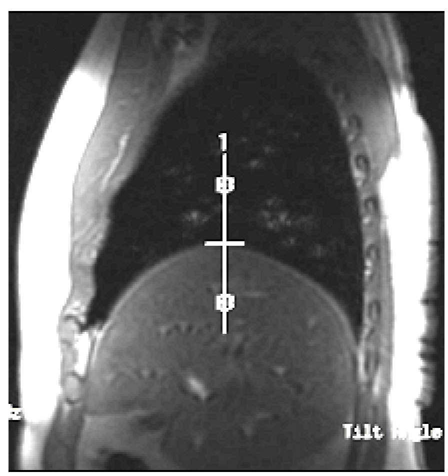
The tracker prescription, as shown in Figure 15-1, has two Rotate handles. One handle is above the prescription and one is below the prescription. The middle cross hair represents the thickness of the tracker and the length is represented by the size of the line.

Figure 15-1 Tracker Graphic Objects



Use the Rotate handles to turn the tracker prescription to angle over the right hemi-diaphragm. You can move the location of the tracker prescription by clicking the prescription and dragging it. Figure 15-2 displays an example of the Navigator tracker prescribed on a sagittal localizer.

Figure 15-2 Navigator Tracker Prescription



The length of the tracker prescription can be adjusted by entering a value in the **Tracker Length (mm)** text box in millimeters or by selecting the value from the drop down list provided. You can also change the thickness of the tracker prescription by entering a value or selecting the value from the drop down list in the **Tracker Thickness (mm)** text box.

Navigator Monitor Window

The Navigator Monitor window (Figure 15-3) opens when the navigator sequence starts scanning. This window remains open for the entire scan. You can close it by clicking the **[Done]** button and then re-open it by clicking the **[Navigator]** button at the bottom of the Scan Operations area. A baseline is acquired first so the system has an idea of how the patient's diaphragm is moving with respiration, represented as a graphed sinusoidal wave.

Figure 15-3 Navigator Monitor Window with Established Baseline

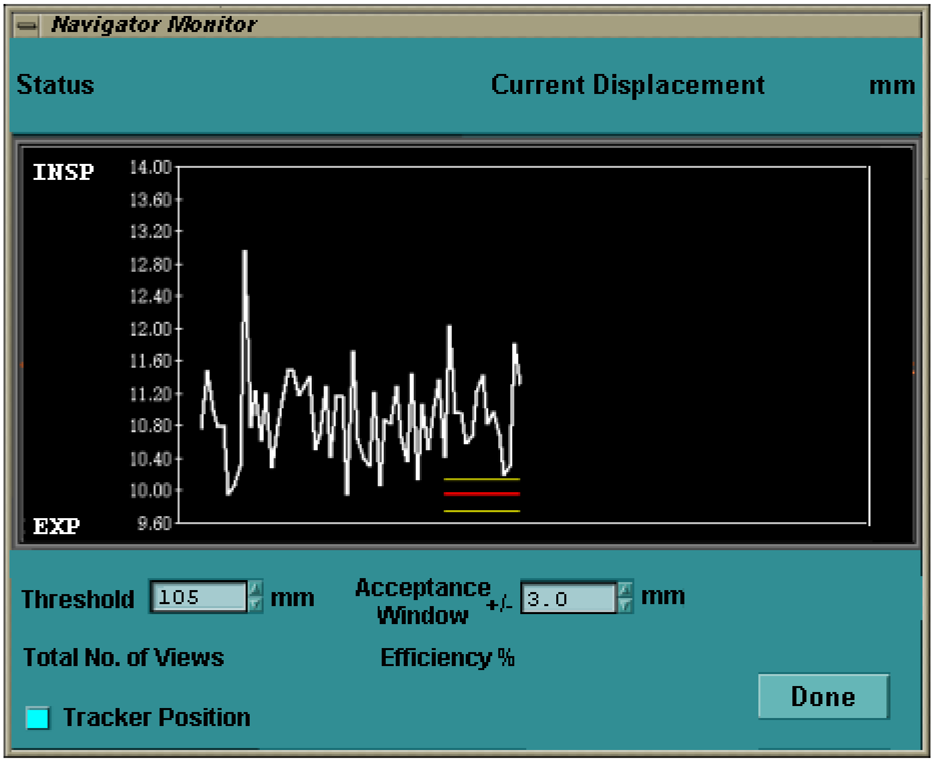


Table 15-2 provides the Navigator Monitor window selections and their descriptions.

Table 15-2 Navigator Monitor Window Functions

Selection	Description
Status	Displays information about the current status of the monitor function in progress.
Current Displacement	Displays the respiratory phase in millimeters. This is calculated after the initial prescan and is updated if you change it.
Threshold	Allows you to change the threshold in steps of 1 mm. The step size is absolute, so if the Navigator autoscales, the perceived displacement of the threshold bar is smaller.

Selection	Description (Continued)
Acceptance Window	Allows you to change the acceptance window in real time. It defaults to ±2 mm. The minimum step size is ±0.5 mm and the maximum is ±10 mm. This allows for any drifts in the baseline of the respiratory cycle during the scan acquisition and/or the flexibility to increase or decrease the total scan time.
Efficiency %	Indicates how often the detected triggers are used for data acquisition. Higher efficiency means you are making good use of all the detected triggers and scan time is improved, but it is not necessarily an indicator of image quality. This depends on your acceptance window and where the data is being acquired (in respect to the respiratory cycle).
Tracker Position	Re-scales the display to accommodate for major changes in a patient's breathing, i.e., the patient's breathing began labored and shallow, but now the patient has relaxed and breathing has slowed. Sometimes setting the threshold does not compensate for this and re-scaling the display helps you set the proper threshold and acceptance window.
Total No. of Views	Indicates the number of views needed to complete the data acquisition.
[Done]	Closes the Navigator Monitor window.

The Status area of the Navigator Monitor window provides four specific pieces of information at various times throughout the scan.

- The first status message indicates a baseline acquisition is in progress.
- The second status message (which appears only momentarily) indicates the threshold is being calculated as the histogram analysis is being carried out.
- The third indicates the displacement of the acquired Navigator pulse from the reference.
- The final message indicates the total scan time in xx:xx mins format.

The system determines the total scan acquisition time by using the calculation shown in Equation 15-1. This initially projected time posts in the scan time countdown area.

Equation 15-1 Navigator Scan Time

$$\textbf{Scan Time} = (\text{\# Phase Encodes} + \text{\# Overscans}) \times \frac{(60 \text{ sec} \div \text{Heart Rate})}{\text{Efficiency \%}}$$

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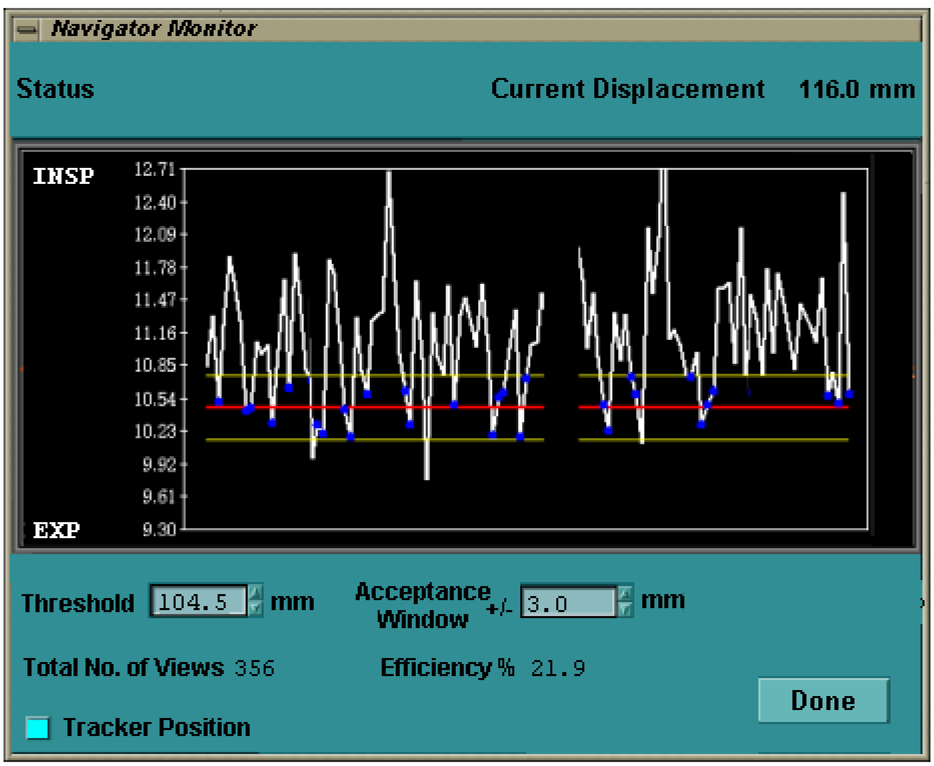
The waveform you observe is an indicator of the movement of the diaphragm, which is affected by respiration. The numbers on the sinusoidal wave graph show the displacement as detected by the tracker in millimeters (Figure 15-4). This graphical representation of the Current Displacement value also provides you with a history of displacement, not only the current value.

This area also illustrates the threshold level, acceptance window, and triggers. The threshold (red line) allows you to set the center point of the acceptance window. The threshold is most commonly set at the level of expiration when the diaphragm is at the most quiescent point. This, along with the acceptance window, defines when cardiac triggers are accepted and data acquisition takes place. The size of the acceptance window (yellow lines) affects how far on either side of the threshold image data is accepted when triggers are detected. The blue points on the waveform indicate where triggers were "seen" and the triggers are only displayed if they fall in the acceptance window.

Figure 15-4 Navigator Monitor Window with Displacement



The line indicating the threshold and the acceptance window updates with each new phase point. The adjustments you make to the threshold value or gating acceptance window are changed dynamically. Widening the acceptance window accepts more triggers, but at the expense of a decrease in image quality (data contains more variance in patient motion).

Efficiency is increased as the window is widened. Increasing the threshold should not affect image quality; it only affects where the data is acquired in the respiratory cycle.

There is a real time counter provided on the Navigator Monitor window to indicate the efficiency of the scan. This counter provides information on the number of views that have been accepted or rejected for the current view. It also provides the efficiency as a percentage using Equation 15-2.

Equation 15-2 Efficiency Equation

% Efficiency = (Accepted views)/(Accepted + Rejected views)

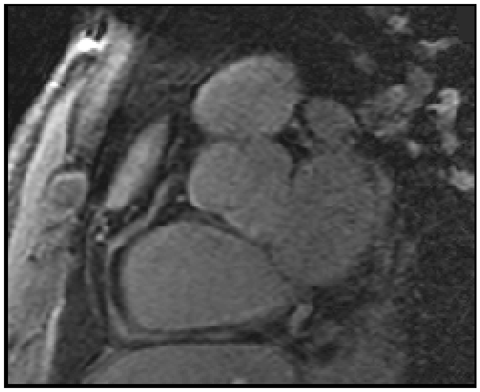
Once the acquisition is completed, the total scan time and the total number of views acquired display in the Status area. The total time for the navigator phase calculation (including sequence play out, data processing, phase computation, and communication time) is 50 ms. This ensures the respiratory position has not changed significantly at the end of the actual scan data collection (in the order of approximately 100 ms for Fast GRE sequence) which follows the navigator echo sequence.

When a new series is prescribed while the current series (with navigator option) is in progress, the navigator window remains in its current state. You are able to close the window by clicking the **[Done]** button, allowing the new prescription to be entered. If you close the Navigator Monitor window, the **[Navigator]** button is ready for re-opening on the Scan Operations area as long the active scan is in progress.

Image Characteristics

A 3D Fast GRE Navigator image (Figure 15-5) demonstrates suppression of the myocardium and improved contrast for the coronary arteries during free-breathing of your patient. The T2 Prep imaging option and SPECIAL fat suppression option have been used when acquiring this Navigator image to visualize the coronary arteries.

Figure 15-5 3D Fast GRE Navigator Image



The images obtained with the navigator feature are labeled with the "/NAV" tag appended to the Imaging Options line on the image, as well as on the text page Imaging Options line.

Applications

Navigator provides better imaging methods for evaluating the coronary arteries. It is useful to acquire free-breathing, coronary artery images in those patients who are unable to hold their breath.

WARNING: **The system cardiac gating waveforms are not to be used for physiologic monitoring. The patient's condition may not be reflected, resulting in improper emergency medical treatment.**

How Do I...

This section provides the step-by-step instructions for imaging with the Navigator imaging technique. Specifically, it describes how to:

- Prescribe a Cardiac Navigator Sequence
- Prescribe Localizer Images with iDrive Pro Plus
- Prescribe the Navigator Tracker
- Monitor the Navigator Pulse

Decision Matrix

A decision matrix is used in this section to provide examples of what values could be selected for prescribing a particular sequence. The purpose of the decision matrix is to help you understand the trade-offs that occur when you change the values for a particular parameter and to provide a framework with which you may build your own unique protocol.

The example protocols provide information on what could be used for these pulse sequences and are not to be considered recommendations by GE Medical Systems. For specific protocols, refer to the protocols on your system.

In addition to listing the information you need to select on the system, the “What You Select” column of the matrix uses two other conventions.

- N/A indicates the imaging parameter is not applicable to the pulse sequence example.
- N/S indicates the imaging parameter is not selectable in the pulse sequence example. The system automatically selects these imaging parameters.

CAUTION: Provide all patients with ear protection prior to any scan to help avoid possible hearing impairment. Acoustic noise levels can exceed 99 dbA in the magnet bore.

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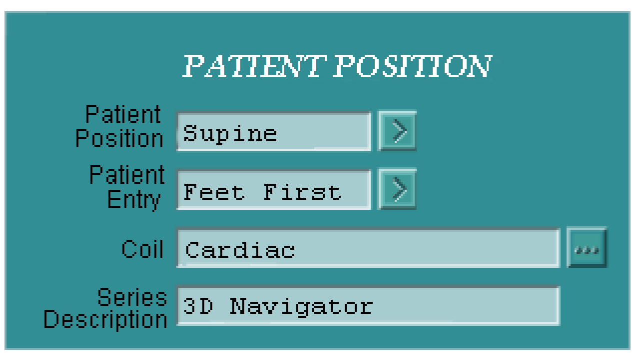
Prescribe a Cardiac Navigator Sequence

The Cardiac Navigator sequence is useful in clinical applications to obtain free-breathing coronary artery images, particularly in those patients who are unable to hold their breath. This technique uses a 3D Fast GRE pulse sequence with the Cardiac Navigator imaging option to acquire the images. T2 Prep is recommended to allow suppression of the muscle and venous structures, while improving visualization of the coronary arteries.

The decision matrix (Table 15-3) is only for prescribing a Cardiac Navigator sequence. The following example protocol is for prescribing an oblique 3D Fast GRE Navigator scan.

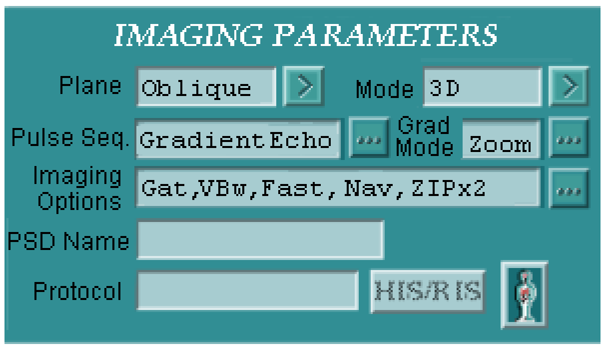
Table 15-3 Cardiac Navigator Protocol Example

Cardiac Navigator Protocol Example		
What You Select		**Selection Notes**
Scan Rx Desktop		
Scan Rx	Acquire a localizer series	Allows Graphic Rx to become available so you can prescribe slices graphically on the localized image. A coronal image from which the lung-liver edge can be visualized is generally the localizer used to prescribe the Navigator tracker. Ensure the image is also appropriate to prescribe the 3D volume over the anatomy of interest.
Rx Manager	**[New Series]**	Adds an additional series to the patient's exam.
Patient Protocol	**[Patient Position]**	Allows you to begin prescribing your new series when the Patient Protocol window becomes active.
Patient Position		
		
Patient Position	**Supine**	Indicates the orientation of the patient. Although compatible with any patient position and entry, supine and feet first are recommended. This ensures accurate cardiac gating/triggering and patient safety by proper routing of gating cables out of the bore, and proper routing of the coil cable to its attachment point on the trolley.
Patient Entry	**Feet First**	

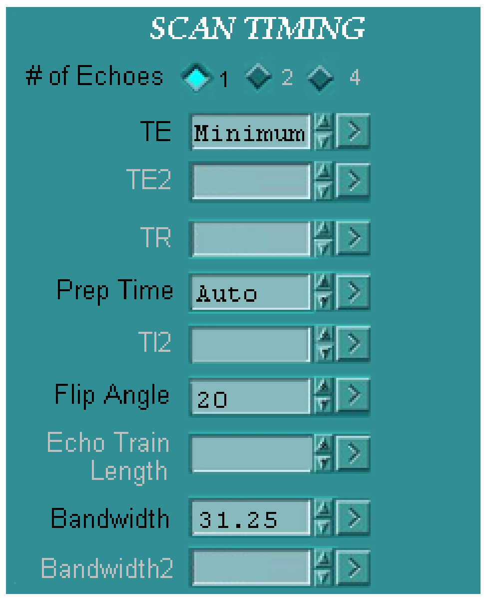
Cardiac Navigator Protocol Example (Continued)

What You Select		Selection Notes
Coil	**Phased Array > Cardiac**	Allows selection of the coil from which the signal is transmitted and received. Use a coil that produces the optimum coverage and SNR.
Series	Enter a series description in the text box.	Allows you to enter a brief description of the series being prescribed. If you do not enter a description, the system enters one for you. The series description default is the selected scan mode, PSD, and selected imaging options.

Imaging Parameters

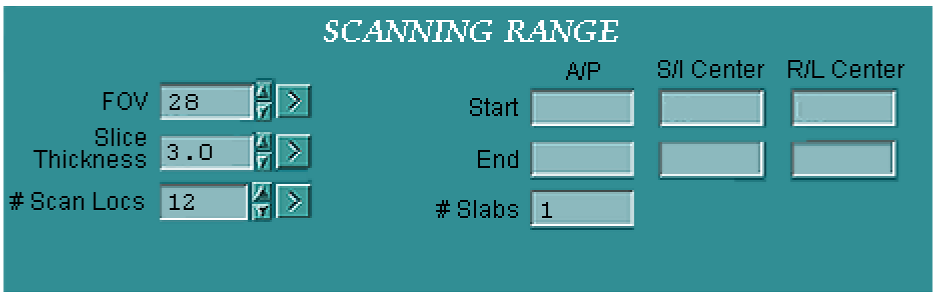


Plane	**Oblique**	Defines the scan plane of the acquisition. Compatible with any scan plane. Select the plane that best meets your clinical need. For cardiac Navigator imaging, select oblique for proper angle through the anatomy.
Mode	**3D**	Prescribes a three-dimensional sequence. 3D must be selected for 3D Cardiac Navigator sequences. The 3D option may only be selected if a valid localizer scan exists for the current patient.
Pulse Seq.	**Fast GRE**	Prescribes the Fast GRE pulse sequence. Only the Fast GRE pulse sequence can be used with the Cardiac Navigator option.
Grad Mode	**Zoom**	Activates the gradient mode of operation. This text box is only available if your system has TwinSpeed™ gradients.
Imaging Options	**Cardiac/ Gating Triggering**, **Variable Bandwidth**, **ZIPx2**, **ZIP512**, **T2 Prep**, and **Navigator. RealTime**	Provides appropriate options for enhancing anatomical features and reducing noise. Cardiac Gating/Triggering should be selected to enable ECG gating and allows the Navigator selection to become available. VBw is used to obtain high bandwidths which results in decreased TE and TR values. The ZIP x2 option gives you higher interpolated slice resolution and ZIP 512 enhances your apparent resolution. Use T2 Prep to suppress the myocardium and increase contrast in the coronary arteries. Select RealTime if your system operates with iDrive Pro Plus so you can acquire the localizers in iDrive.
PSD Name	N/A	
Protocol	N/A	

Cardiac Navigator Protocol Example (Continued)		
What You Select		**Selection Notes**
Additional Parameters - SAT		
		
3-Plane SAT	**Fat**	Enables the SPECIAL fat suppression technique. SPECIAL cannot be used if IR Prepared is selected at the Imaging Options window.
Scan Timing		
		
# of echoes	N/S	One echo is selected automatically.
TE	**Minimum**	Typically, a Minimum TE is used to obtain low TR values for maintaining short scan times. Minimum Full is recommended with 0.5 NEX.
TE2	N/A	
TR	N/S	The minimum TR is selected automatically. The minimum TR is posted in the Min. column to the right of the TR text box. The minimum TR may decrease as RBw is increased and as the Frequency matrix decreases.
Prep Time	**Auto**	The system allows automatic selection of the Prep Time when SPECIAL is turned on.
TI2	N/A	

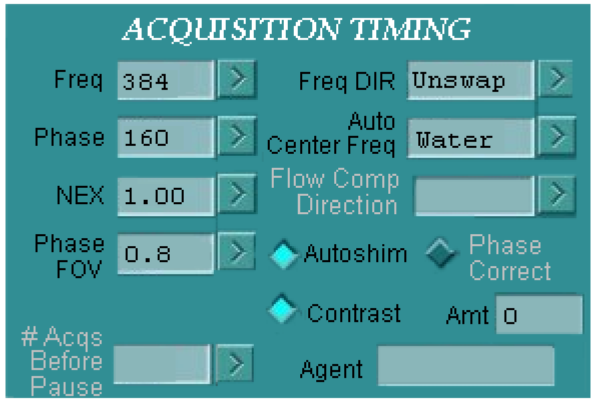
Cardiac Navigator Protocol Example (Continued)		
What You Select		**Selection Notes**
Flip Angle	Enter **20** in the text box.	The typical flip angle values are 15° or 20°. The use of higher flip angles in cardiac imaging increases the saturation of the myocardium.
Echo Train Length	N/A	
Bandwidth	**31.25**	The typical RBw value is 31.25 kHz. As the bandwidth increases, minimum TR and TE values may decrease.
Bandwidth2	N/A	

Scanning Range



FOV	Enter **28** in the text box.	Defines the size of the area imaged. The FOV is generally set as small as possible to obtain the acceptable resolution and SNR without causing aliasing from outside the FOV into the anatomy of interest. Typical values are 20 to 32 cm.
Slice Thickness	**3.0**	Defines the thickness of the image slice. With the ZIPx2 option on, interpolated slice thickness becomes 1.5 mm.
Scan Locs	**12**	Defines the number of scan locations per 3D slab. Typically, the maximum should not exceed 20 and the minimum should not exceed 8.
Start, End Locations		Determines the start and end locations from the Graphic Rx program after the slab is prescribed and posts the locations here.
# Slabs	**1**	Determines the number of slabs as prescribed in Graphic Rx and posts it here. The number of slabs cannot be greater than one.

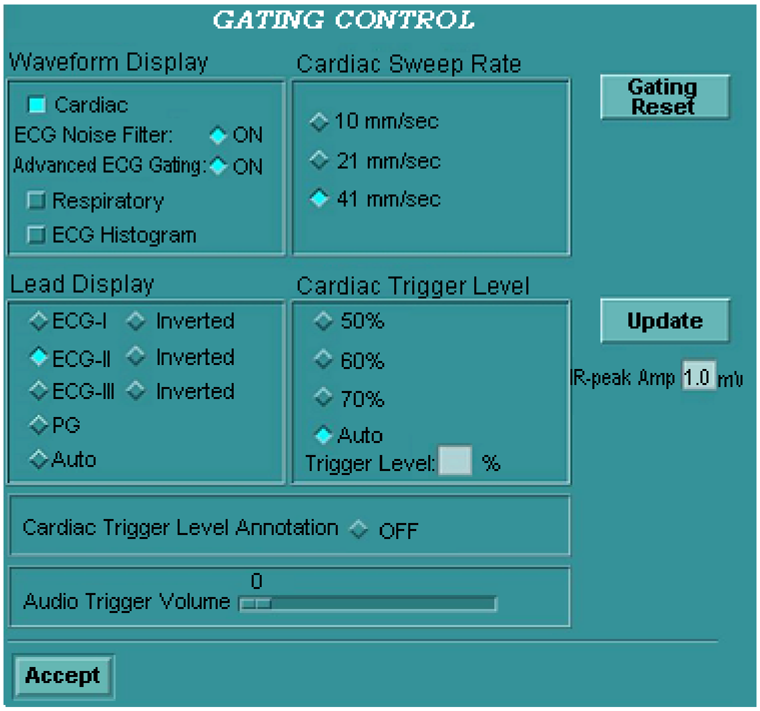
Cardiac Navigator Protocol Example (Continued)		
What You Select		**Selection Notes**
Acquisition Timing		



Freq	**384**	Controls resolution. Increasing the frequency matrix decreases SNR and the number of slice locations allowed, while increasing resolution.
Phase	**160**	Controls scan time and resolution. The phase matrix cannot exceed the frequency matrix.
NEX	**1**	One NEX is generally used to maintain acceptable scan times.
Phase FOV	**0.8**	Shortens scan time by scaling down the FOV in the phase direction by either 0.5, 0.6, 0.7, 0.8, or 0.9. Reduces the phase matrix and thus decreases scan time, decreases the FOV in the phase direction, and decreases SNR slightly. The phase FOV dimension is displayed next to the phase FOV factor.
Freq DIR	**Unswap**	Displays the default frequency direction, which is typically the long axis of the image. Leave the frequency direction unswapped.
Auto Center Freq	**Water**	Sets the peak center frequency on the water peak of the patient during prescan.
Flow Comp DIR	N/A	
Autoshim	**On**	Improves image quality and is recommended for this sequence.
Phase Correct	N/A	
Contrast	**On**	Enter a value of **0** for the contrast amount. This value turns on the required reconstruction algorithm for navigator. Leave the **Agent** text box blank.
# of Locs Before Pause	N/A	

Cardiac Navigator Protocol Example (Continued)

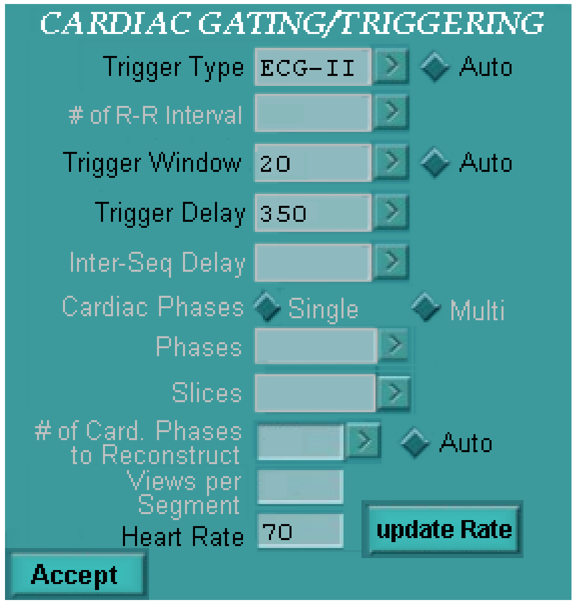
What You Select		Selection Notes
Gating Control		



ECG Noise Filter	**On**	Designed to improve gating detection at the expense of a time delay from when the QRS complex is generated to when Signa detects it. The default position is on, leave ECG Noise Filter in the on state.
Advanced ECG Gating	**On**	Designed to improve trigger detection in ECG Gated scans by detecting which component of the QRS complex is the correct trigger. The default position is on, leave Advance ECG Gating in the on state.
Lead Display	**ECG-II**	Test all leads and select the lead that produces the highest R-peak Amplitude, which should be at least 1.0 mV. If the mV is less than 1.0, repeat the preparation procedure and reposition the electrodes.
Cardiac Trigger Level	**Auto**	Auto trigger is the default and sets the ECG trigger level to 65% (the range is 30-90%). Reduce the trigger level to 50% if the trace is good but triggers are missing.
Gating Reset	**[Gating Reset]**	Click to re-initialize the gating subsystem if: - The waveform is noisy. - Triggers are being missed. - The waveform is inverted. - The system is unable to find valid triggers due to patient activity such as sudden motion.
Accept	**[Accept]**	Confirms the selected values and closes the Gating Control window.

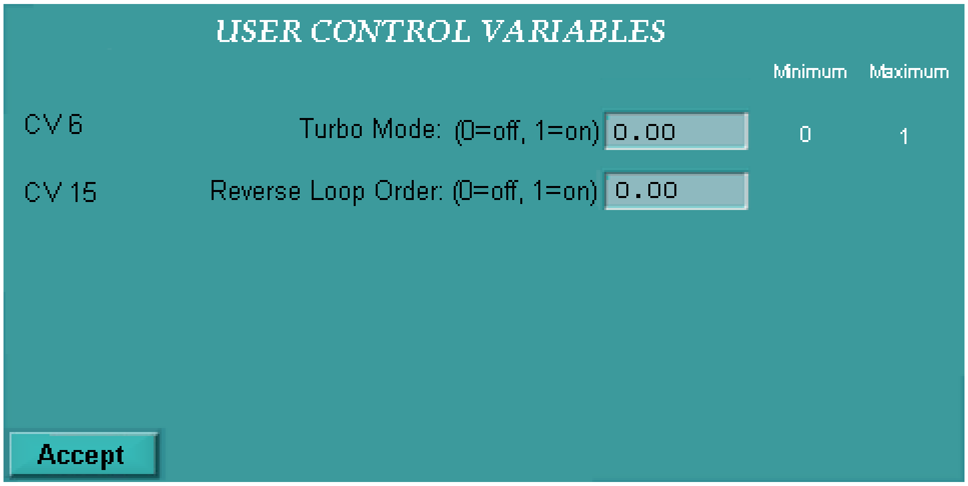
Cardiac Navigator Protocol Example (Continued)

What You Select		Selection Notes
Additional Parameters - Gating/Triggering		



Trigger Type	Select the best lead.	Defines which signal is sent by the cardiac monitor to activate the data acquisition. When ECG gating, select the lead that provides the best signal.
# of R-R Interval	N/A	
Trigger Window	**20**	Defines the period of time where no data is acquired and the system is waiting for the next R-wave trigger. Values of 10 to 20 are commonly used. Use larger values for patients with irregular heart rates.
Trigger Delay	**350**	Defines the delay time between the occurrence of the triggering pulse and the actual onset of imaging. Recommend imaging is at diastole, as this is when the heart is the quietest and when coronary flow is maximized. The diastolic value is heart rate dependent. Heart rate ranges from 60 to 85 BPM usually have delay times around 350. The lower the heart rate, the higher the trigger delay time.
Inter-Seq Delay	N/A	
Cardiac Phases	N/A	
# of Card. Phases to Reconstruct	N/A	
Views per Segment	N/A	
Heart Rate	**[update Rate]**	Lets the system obtain an automatic reading of the current heart rate. Updates the rate prior to beginning the scan.
Accept	**[Accept]**	Confirms the selected values and closes Gating/Triggering Additional Parameter screen.

Cardiac Navigator Protocol Example (Continued)		
What You Select		**Selection Notes**
Additional Parameters - User CVs		



Turbo Mode	Enter **0.00** in the text box.	Disables Turbo mode.
Reverse Loop Order	Enter **0.00** in the text box.	Disables Reverse Loop Order. Turning Reverse Loop Order off, acquires one phase encoding line for each slice, every heartbeat. This is the desired method of acquisition.
Accept	**[Accept]**	Confirms the selected values and closes the User CVs Additional Parameter screen.

Additional Parameters - Graphic Rx

iDrive Pro Plus		Refer to the procedure “Prescribe localizer images with iDrive Pro Plus,” if your system operates with iDrive Pro Plus.
[+] Next and **[-]** Prior	**[+]** and **[-]**	Allows you to page through the localizer images to check the position of the prescription.

Cardiac Navigator Protocol Example (Continued)		
What You Select		**Selection Notes**
Image Viewport	Press the **Shift** key and click the image to display the 3D volume.	Allows you to prescribe 3D slab over the anatomy of interest. Select the adjustment handles to angle the slab.
Copy Rx	**[Copy Rx]** (optional)	Copies the exact locations of the prior series if you had previously graphically prescribed a series with the same plane, FOV, and slice thickness.
Erase All	**[Erase All]** (If necessary)	Eliminates the graphic prescription from the screen and allows you to start over.
Reset Center	**[Reset Center]** (if necessary)	Re-establishes the FOV center on a different localized slice.
Tracker Rx	**[Tracker]**	Allows you to place the Navigator Tracker on the image. Refer to the procedure “Prescribe the Navigator Tracker.”
Accept	**[Accept]**	Confirms the cursor position and closes Graphic Rx.
Series Control		
Save Series	**[Save Series]**	Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
Rx Manager		
Prepare to Scan	**[Prepare to Scan]**	Downloads the series.
Scan Operations		
Prep Scan	**[Prep Scan]**	Performs Auto Prescan and readies the system for data acquisition. Select for breath-hold acquisitions.
Scan	**[Scan]**	Initiates the acquisition.

Quick Steps: Prescribe Localizer Images with iDrive Pro Plus

1. Click **[Scan]** to initiate iDrive Pro Plus.
2. Change the slice thickness from 16 to 8.
3. Select the coronal reference image.
4. Click **[Define Scout]**.
5. Click **[Draw Line]**.
6. Click **[Save Image]** when the diaphragm is in the most superior location (expiration).
7. Click **[Draw Line]** to turn the line tool off.
8. Select the coronal reference image.
9. Click **[Step]** and position the cursor so that the arrow is pointing either towards or away from you.
10. Click the left mouse button until you see a good heart image.
11. Click **[Save Image]**.

Prescribe Localizer Images with *i*Drive Pro Plus

These instructions only apply if your system operates with iDrive Pro Plus. Use iDrive Pro Plus to acquire two sets of localizer images: one set of localizer images from which to position the tracker pulse and another set from which to prescribe the 3D volume.

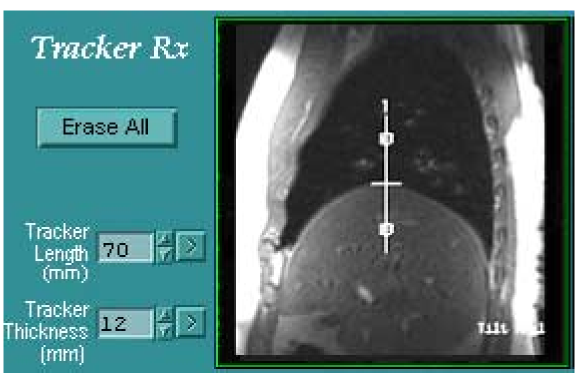
1. Click **[Scan]** to initiate iDrive Pro Plus.
2. Change the slice thickness from 16 to 8.
    - This improves image resolution.
3. Select the coronal reference image.
4. Click **[Define Scout]**.
5. Click **[Draw Line]**.
    - Position the vertical line cursor over the right diaphragm.
6. Click **[Save Image]** when the diaphragm is in the most superior location (expiration).
    - Acquire several sagittal images for tracker pulse positioning.
7. Click **[Draw Line]** to turn the line tool off.
8. Select the coronal reference image.
9. Click **[Step]** and position the cursor so that the arrow is pointing either towards or away from you.
    - The arrow direction indicates the direction you are going to step the Realtime image. You want to step the image towards the heart.
10. Click the left mouse button until you see a good heart image.
11. Click **[Save Image]**.
    - Acquire several coronal images for positioning the 3D volume.

Prescribe the Navigator Tracker

The Navigator Tracker synchronizes the acquisition to the end-expiration respiratory phase of your patient, thus minimizing respiratory ghosting artifacts. During scan prescription, you enable the navigator pulse by selecting the Navigator option on the Imaging Options window. The Graphic Rx Additional Parameter gives you access to the Tracker Rx screen, allowing you to prescribe the Navigator Tracker.

Use the following procedure to prescribe the Navigator Tracker from the 3-Plane GRx window.

1. Display an image on which the liver-lung edge can be visualized.
   - Use the **[+]** Next and **[-]** Prior buttons to page through the localizer images.
2. Deposit the Navigator Tracker on the image.
   a) Click **[Tracker]** to open the tracker graphic controls.
   b) Position the cursor over the desired anatomy.
   c) Press the **Shift** key and click to deposit the Navigator Tracker on the image.
3. Place the center tic-mark of the tracker line at the liver-lung edge of the right lobe.
   - The tracker line should be as lateral as possible.
     – If placed too close to midline, the tracker pulses may interfere with the anatomy of interest (if performing cardiac imaging), causing artifacts.



Tracker Positioning on Right Hemi-diaphragm

4. Enter **70** in the **Tracker Length** text box.
   - The tracker length should not overlay the 3D volume.

Quick Steps: Prescribe the Navigator Tracker

1. Display an image on which the liver-lung edge can be visualized.
2. Deposit the Navigator Tracker on the image.
3. Place the center tic-mark of the tracker line at the liver-lung edge of the right lobe.
4. Enter **70** in the **Tracker Length** text box.
5. Enter **12** in the **Tracker Thickness** text box.
6. Adjust the position of the Navigator Tracker.
7. Click **[Accept]** to close the Tracker Rx window.

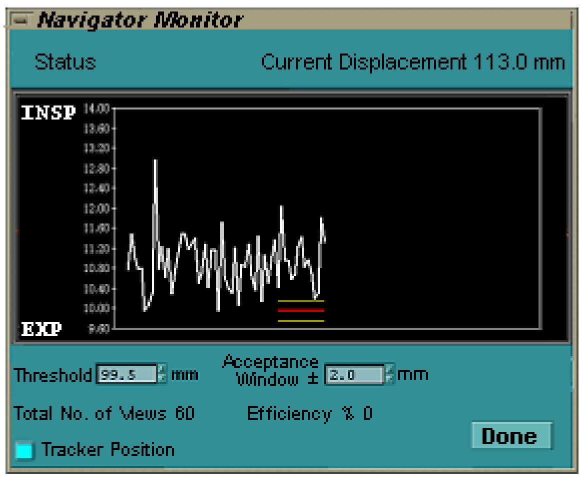
5. Enter **12** in the **Tracker Thickness** text box.
   - The tracker width should not overlay the 3D volume.
   - Be cautious with the tracker size. Only one tracker pulse is seen on your image. Two tracker gradient pulses are applied with the Navigator sequence. You can think of the second pulse being applied at a 45° angle to the tracker line you have deposited.
6. Adjust the position of the Navigator Tracker.
   - Move or angle the tracker using the handles.
7. Click **[Accept]** to close the Tracker Rx window.
8. Click **[Accept]** to close the 3-Plane GRx window and accept the prescription.

Monitor the Navigator Pulse

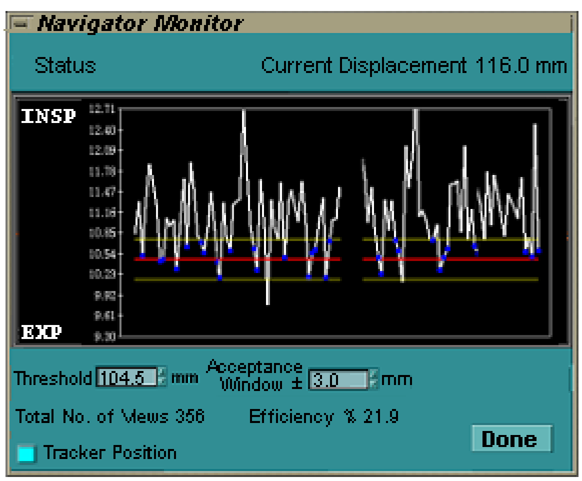
When you begin the Navigator acquisition, the Navigator Monitor window opens on the Scan Rx Desktop. Your MR system determines and displays a baseline respiratory cycle. The status area of the Navigator Monitor window indicates the baseline is being acquired. As the status of the scan changes, the status area updates to reflect the current status of the scan.

Use the following procedure to monitor and adjust the Navigator pulse during data acquisition to accommodate for drifts in your patient's respiratory cycle.

1. View the baseline respiratory waveform and phase displacement of the Navigator Tracker.
   - The threshold and acceptance window are graphically marked on the monitor window.



Navigator Monitor with Baseline Display



Navigator Monitor with Displacement Display

Quick Steps: Monitor the Navigator Pulse

1. View the baseline respiratory waveform and phase displacement of the Navigator Tracker.
2. Adjust the displacement of the Navigator Tracker, if necessary.
3. Click **[Done]** to close the Navigator Monitor window.

2. Adjust the displacement of the Navigator Tracker, if necessary.
    a) Enter a value in the **Threshold** text box.
        – This shifts the threshold displacement according to the value.
        – Alternatively, click the arrows to change the threshold value in ±1 mm increments.
    b) Enter a value in the **Acceptance Window** text box.
        – This widens or narrows the acceptance window according to the value.
        – Increasing the acceptance at this point improves data acquisition time.
        – Alternatively, click the arrows to change the threshold value in ±2 mm increments.
3. Click **[Done]** to close the Navigator Monitor window.
    - The window can be re-opened at any time by clicking **[Navigator]** in the Scan Operations area of the Scan Rx Desktop.

Chapter 16

Bolus Chasing

Introduction

Bolus Chasing is a technique used in imaging a bolus of contrast as it travels through the vessels. It is usually performed in conjunction with a bolus triggering technique.

This chapter explains the automated multi station technique for contrast enhanced peripheral vascular angiography. It contains the step-by-step instructions to help you learn how to:

- Prepare the Patient
- Scan the Localizer Series
- Set up the Scan Parameters
- Set up the Graphic Parameters
- Scan the SmartStep Series
- Copy and Paste a SmartStep Series
- Scan using the GE Saved SmartStep Protocol

In addition, this chapter answers the following questions:

1. What is SmartStep used for?
2. What is a meta-series?
3. How does elliptic-centric k-space filling affect image contrast?
4. What is Turbo mode?
5. Why would I want to use a mask series?
6. How do I prescribe a mask series?

What Do I Need to Know About...

This section presents the concepts necessary to successfully complete the SmartStep process. Specifically, you need to understand:

- SmartStep Basics
- Contrast Mechanism
- SmartStep User Control Variables
  - Meta-Series
  - Image Acquisition Delay
  - Turbo Mode
  - SPECtral Inversion At Lipids (SPECIAL)
  - K-space
  - Acquisition Type

SmartStep Basics

SmartStep (Multi Station) is an optional feature that provides automatic table movement and switching of prescribed coils between stations, including body to phased array, and/or between phased array elements. SmartStep is used with 3D Fast Time Of Flight Gradient Echo (TOF GRE)/SPoiled Gradient Echo (TOF SPGR), and 3D Fast GRE/SPGR pulse sequences.

Contrast Mechanism

SmartStep is used to chase a bolus of contrast down the lower extremities. In contrast-enhanced Magnetic Resonance Angiography (CEMRA), the mechanism used is the T1 shortening effect of gadolinium and not flow enhancement. Gadolinium shortens the T1 of blood from 1200 ms to approximately 100 ms. Consequently, slice locations can be prescribed so the vessels run in plane and not through plane. In Figure 16-1, images are displayed of both flow and contrast enhancements.

Figure 16-1 Flow vs. Contrast Enhanced Images

Flow Enhancement

Contrast Enhancement

SmartStep User Control Variables

There are several User Control Variables (User CVs) located on the User CVs Screen. The number of options is dependent on several factors including gradient configuration, selected Imaging Options, and whether the prescription is for the first or subsequent stations. Figure 16-2 and Figure 16-3 display the User CV options available with the SmartPrep feature prior to selection of number of stations. Figure 16-4 displays the User CV options for the second and subsequent stations.

Figure 16-2 SmartStep User CVs Screen (Page 1)

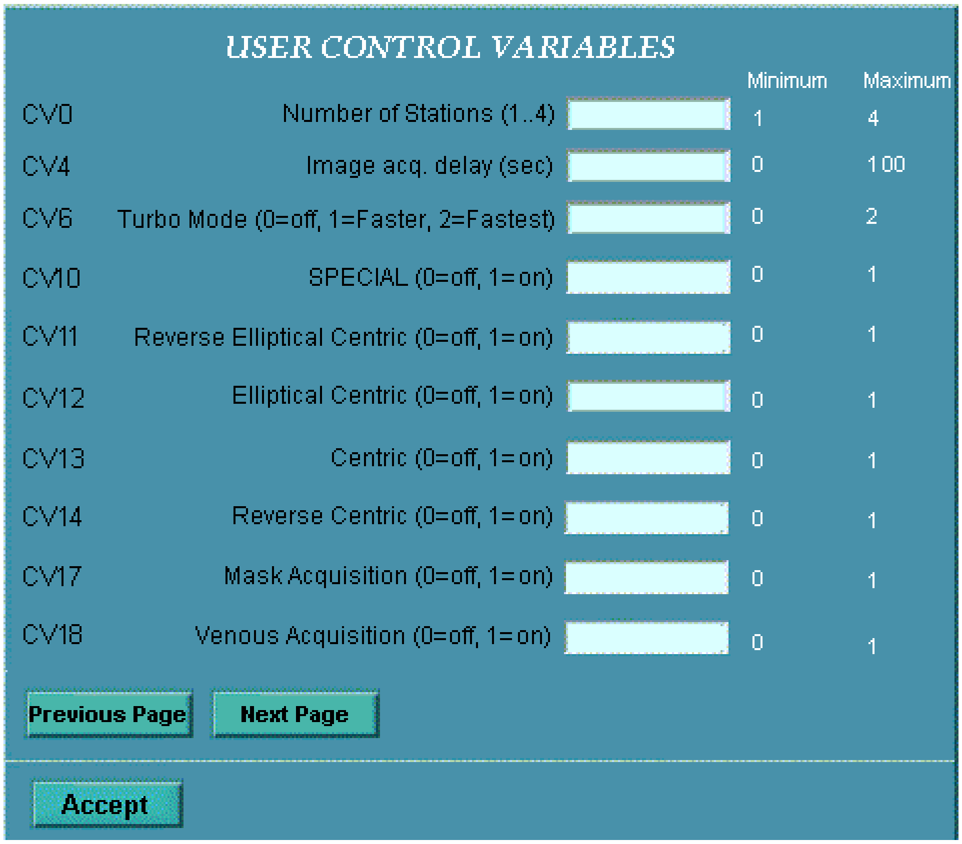


Figure 16-3 SmartPrep User CVs Screen (Page 2)

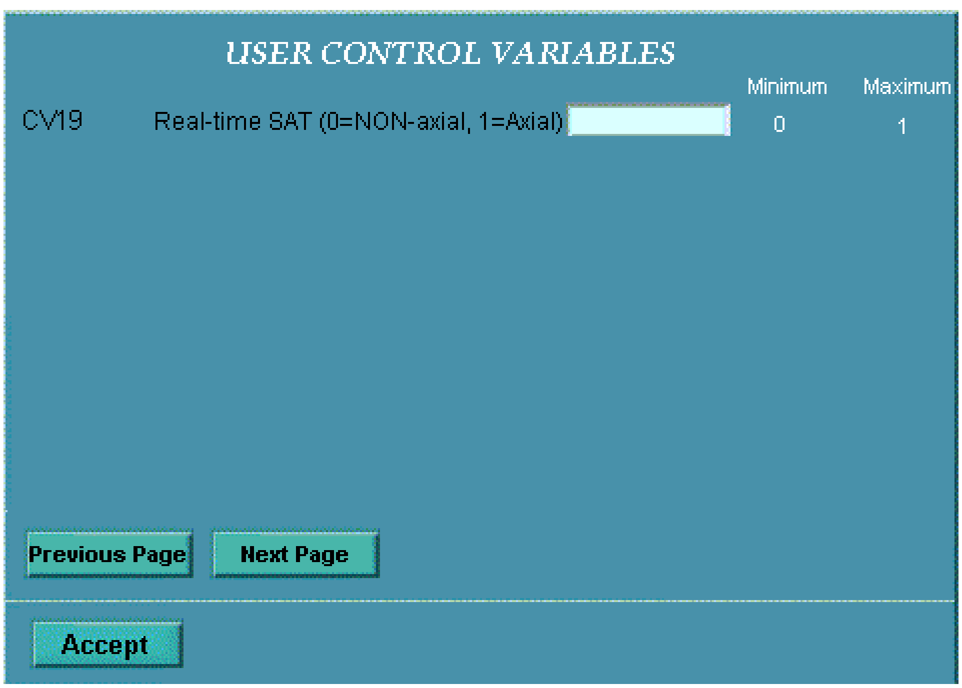
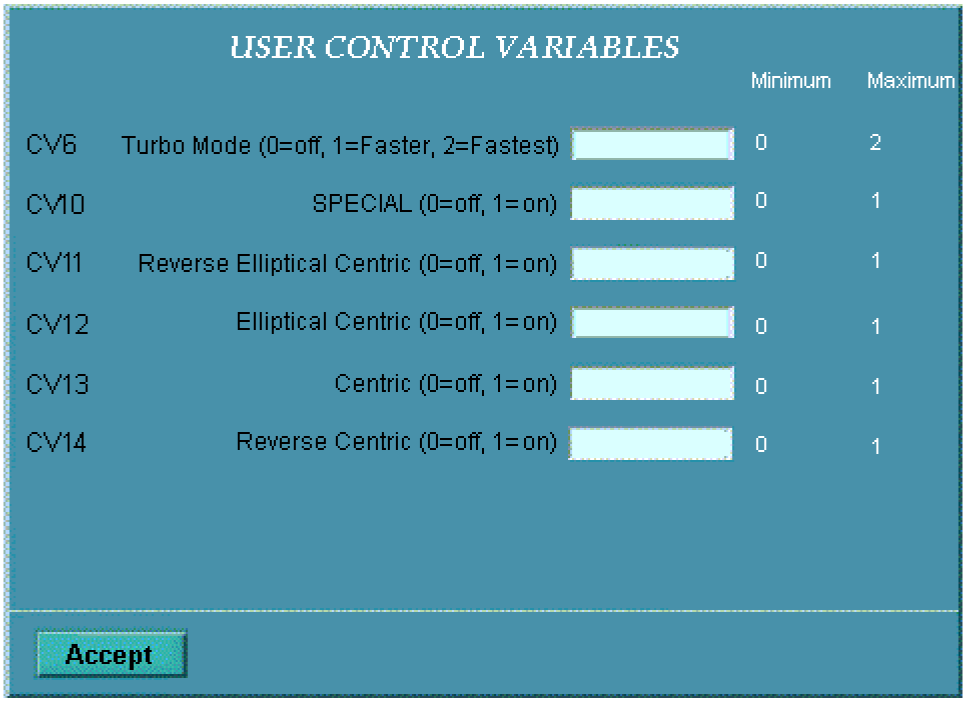


Figure 16-4 User CV Window (second and subsequent stations)



Meta-Series

A meta-series consists of multiple series linked together. You can link up to four series together at one time. By doing so, the scanner automatically moves the table after each series to the next pre-determined point, as well as switches on and off the appropriate coils, you selected at the time of set up.

The Multi Station Imaging Option must be selected for the system to automatically create a Meta-series, once the first series is saved. You can then edit the changes you want made to the parameters.

If your site uses a protocol with a different number of stations, save one protocol for each scenario. For example, save one protocol for a three station SmartStep and save another protocol for a four station SmartStep. Once a protocol is saved with the Multi Station Imaging Option and a set number of stations selected, the number of stations value cannot be changed.

NOTE: The Multi Station Imaging Option cannot be turned off after it has been saved in a series. Therefore, if you try to turn it off after performing a copy/paste or after loading a protocol that has it on, an error message appears.

You have the ability to select scan parameters unique for each station, with the exception of Plane, Scan Mode, and Pulse Sequence. Figure 16-5 displays an example of a three station meta-series. Table 16-1 provides the descriptions of areas pointed out in Figure 16-5.

Figure 16-5 Rx Manager of Three Station Meta-series

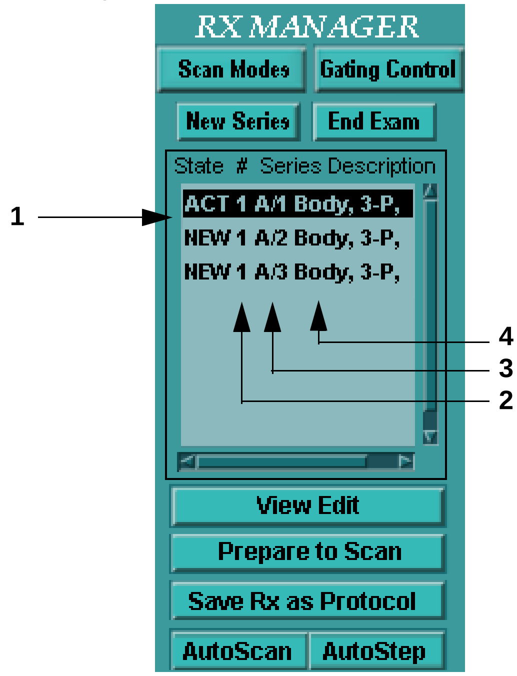


Table 16-1 Descriptions of Figure 16-5 Components

Numbers	Description
1	This area displays the state of the meta-series. • **NEW** represents the series has just been created; nothing has been done to it yet. • **INRX** represents the series is currently in the view/edit mode. • **RXD** represents the series has been prescribed. • **ACT** represents the series is in an active state and has been downloaded. • **PSCD** represents the series has been prescanned. • **SCND** represents the series has been scanned.
2	This area displays the series number. Figure 16-5 displays a 1 in this column, which signifies the first series for this exam. **NOTE:** The series number is displayed for each station of the meta-series.

Numbers	Description (Continued)
3	This area represents the acquisition type and the station number. • “M” represents Mask Phase • “A” represents Arterial Phase • “V” represents Venous Phase The number after the phase distinction represents the station (meta-series) number.
4	This area represents the series description. It displays a shortened version of the series description you entered in the Patient Position area. If nothing has been entered for the series description, the system automatically enters one for you. It includes the coil type and the scanning plane. An example of this is shown in Figure 16-5. **NOTE:** You can change the series description for each station once you are in view/edit mode for that station.

Image Acquisition Delay

Image Acquisition Delay is an option that allows you to enter a scan pause time before the start of your acquisition. The maximum delay time is 100 seconds; it is entered on the **User CVs Screen**. The delay period begins after the **[AutoStep]** button is clicked. This delay applies only to the first station of the mask, arterial, and venous phases. The monitor and the magnet enclosure displays and counts down the delay time you entered. After the delay time reaches zero, your system displays the acquisition time and the system begins to scan.

Turbo Mode

Turbo mode is available on Hi*Speed*™ Plus, Echo*Speed*™, and Twin*Speed*™ systems as a User CV for Fast TOF and Fast GRE/SPGR pulse sequences. It reduces the width of the RF pulse and allows shorter TR periods, thus shorter total scan times. This option performs in two modes: faster and fastest. Table 16-2 lists the required text entries for the available modes and the changes in the RF time with each selection.

Table 16-2 Turbo Mode User CV

Turbo Mode Text Box Entry	Mode	RF Duration
0	Turbo Mode off	1.6 ms
1	Turbo Mode on Faster	0.8 ms
2	Turbo Mode on Fastest	0.6 ms

SPECIAL

SPECIAL is Spectral Inversion at Lipids is a fat suppression technique that uses a 180° inversion pulse to nullify the signal from fat. This option is not compatible with Elliptic-centric or Reverse Elliptic-centric k-space filling. SPECIAL is turned on when Fat SAT is selected from the Saturation window. Selection of SPECIAL results in a Prep Time display on the Scan Timing screen.

NOTE: Refer to the Imaging Options chapter for additional information on the SPECIAL feature.

K-Space Filling

When using SmartStep, there are several ways to fill k-space. The options in Table 16-2 can be found on the User CVs screen.

Table 16-3 K-Space Filling Options

K-Space Filling Options	Fills K-Space How...
Reverse Elliptical-centric	Fills outer lines and outer slices first.
Elliptical-centric	Fills the center lines and center slices first.
Centric	Fills the center lines first.
Reverse Centric	Fills the outer lines first.

In addition, these methods of k-space filling are no longer linked to SmartStep or SmartPrep. Centric and Elliptic-centric can be used with any Fast GRE or Fast SPGR scan prescription.

Acquisition Type

There are three acquisition types that can be used with SmartStep.

- Mask Acquisition
- Arterial Acquisition
- Venous Acquisition

Mask Acquisition scans the prescribed stations prior to administration of contrast. Arterial Acquisition scans all prescribed stations for contrast in the arterial phase. Venous Acquisition scans all prescribed stations for contrast in the venous phase. You can use all three acquisition types within the same examination series. The Acquisition type is displayed in the Rx Manager, located on the Scan Desktop. Figure 16-5 displays an example of an Arterial Acquisition. Enter a `1` in the **Mask** and/or **Venous** text boxes to turn this feature on. Enter a `0` in the **Mask** and/or **Venous** text boxes to turn this feature off.

NOTE: The mask and venous series will not appear in the Rx Manager until after the prescan has been completed for the meta-series. The Rx Manager automatically updates and posts all acquisition types you selected from the User CVs Screen.

The acquisition order of the meta-series has changed from previous software versions. Refer to Table 16-4 for the order of acquiring each type of meta-series using SmartStep.

Table 16-4 Meta-Series Acquisition Order

Meta-Series	Order of Scan
Prescan	Bottom, middle, top
Mask	Top, middle, bottom
Arterial	Top, middle, bottom
Venous	Bottom, middle, top

Real-Time SAT

The Real-time SAT User CV appears only if Fluoro Trigger is selected from the Imaging Options window. It is not available on systems that have *i*Drive Pro.

Real-time SAT applies saturation pulses when Real-time is open. When selected, it improves the contrast between the bolus and the surrounding tissue.

- Select 0 when the plane you are viewing in Real-time is either a sagittal or coronal.
- Select 1 when the plane you are viewing in Real-time is an axial plane. The saturation pulses are placed outside the slice and move with the slices as you traverse through the anatomy.

How Do I...

This section provides the step-by-step instructions for bolus chasing using SmartStep. Specifically, it describes how to:

- Prepare the Patient
- Scan the Localizer Series
- Set up the Scan Parameters
- Set up the Graphic Parameters
- Scan the SmartStep Series
- Copy and Paste a SmartStep Series
- Scan using the GE Saved SmartStep Protocol

NOTE: The first five sets of steps must be followed in the order provided above to successfully perform a SmartStep examination.

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Prepare the Patient

Use this procedure to perform a scan with SmartStep. With SmartStep, the system automatically advances the table and starts the next prescribed series.

You should already know how to setup a protocol for your system; only a brief review is provided. The rest of the procedure guides you through the SmartStep scanning process.

NOTE: It is suggested you use SmartPrep or FT MRA, if you have it on your system. This takes the guesswork out of bolus timing.

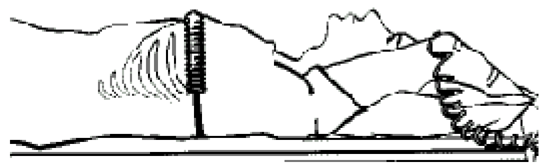
Refer to Working Safely chapter in Volume 1 for important information regarding patient safety.

1. Select the appropriate coil.
   - Refer to the Gradient, Shim, and Imaging Coils chapter in Volume 1 for suggested coil positioning.
   - It is recommended you use the Peripheral Vascular (PV) coil for a bolus chasing examination, although the body coil can also be used.
2. Position the patient feet first.
   - This ensures the patient's head is close to the magnet entrance, making it easier to give breathing instructions.
3. Elevate the patient's legs with sponges.
   - This step is not needed, if using the peripheral vascular coil.
   - This places your patient's legs parallel to the table.
4. Place Respiratory Bellows on the patient (optional).
   - This is helpful in detecting when and how long your patient is suspending respirations during breath holding techniques.
   - Refer to the Gating and Triggering chapter in Volume 3 for correct placement techniques.
5. As directed by your physician, set up the patient IV catheter.
   - Follow your physician's or facility's guidelines.

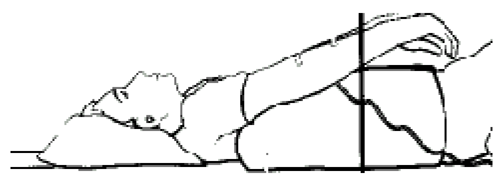
Quick Steps: Prepare the Patient

1. Select the appropriate coil.
2. Position the patient feet first.
3. Elevate the patient's legs with sponges.
4. Place Respiratory Bellows on the patient (optional).
5. As directed by your physician, set up the patient IV catheter.
6. Prepare the power injector (optional).
7. Bring your patient's arms above their head.
8. Press **Landmark** to landmark your patient.
9. Record off-sets of remaining stations you wish to scan.
10. Press **Move to Scan**.

6. Prepare the power injector (optional).
   - Follow your power injector specifications.
   - If a power injector is not used, follow your facility's procedure for administering rapid bolus injections.
7. Bring your patient's arms above his or her head.
   - This minimizes the chance for a wrap around artifact.
   - If the patient's arms cannot be placed above the head, elevate the arms on cushions, to help minimize wrap around artifact.

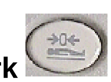


Arms above patient's head



Arms resting on cushions

Display of Patient Arm Position

8. Press **Landmark**  to landmark your patient.
   - Landmark for your first station only.
9. Record off-sets of remaining stations you wish to scan.
   - It is recommended you use the suggested off-sets.
   - If the suggested off-sets are not used with the PV coil, images may result in coil cut-off.
   - Use the align light to record the location of any additional off-sets.
10. Press **Move to Scan** .

Scan the Localizer Series

Use this procedure following the patient preparation portion of the exam. The steps provided give you instructions on how to set up and scan a multi station meta-series localizer.

1. Click the **Patient Position** icon.
   - Located on the Scan Desktop.
2. Select **Coil > PVUPPER**.
   - It is recommended you use the Peripheral Vascular (PV) coil for a bolus chasing examination, although the body coil can also be used.
3. Enter a description in the **Series Description** text box.
   - Suggested name is “Top Loc”.
4. Select **Plane > 3 Plane**.
   - Located in the Imaging Parameters area.
5. Select **Mode > 2D**.
   - Located in the Imaging Parameters area.
6. Select **Localizer** in the Pulse Sequence window.
7. Click **[Accept]**.
   - This registers the pulse sequence for your acquisition.
8. Select **Grad Mode > Whole**, if applicable.
   - The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.
9. Select **No Phase Wrap** from the Imaging Options window.
   - **No Phase Wrap** (NPW) prevents aliasing of anatomy inside a prescribed field of view (FOV).
10. Click **[Accept]**.
    - This registers the imaging options into your current acquisition.
11. Enter values into the **Center FOV** text boxes.
    - Suggested parameters: 0 S/I, 0 A/P and 0 R/L.

Quick Steps: Scan the Localizer Series

1. Click the **Patient Position** icon.
2. Select **Coil > PVUPPER**.
3. Enter a description in the **Series Description** text box.
4. Select **Plane > 3 Plane**.
5. Select **Mode > 2D**.
6. Select **Localizer** in the Pulse Sequence window.
7. Click **[Accept]**.
8. Select **Grad Mode > Whole**, if applicable.
9. Select **No Phase Wrap** from the Imaging Options window
10. Click **[Accept]**.
11. Enter values into the **Center FOV** text boxes
12. Enter the **Number of Slices** into the text box.
13. Enter the remaining imaging parameters.
14. Click **[Save Series]**.
15. Select the localizer in the Rx Manager, right-click, and select **Copy** from the pull-down menu.
16. With the cursor still in the Rx Manager, select **Paste**, then **Paste** again.

Quick Steps: Scan the Localizer Series cont.

17. Select the second localizer in the Rx Manager and click **[View Edit]**.
18. Change the description of the series.
19. Change coil type, if necessary.
20. Change Center FOV off-set to `I420`.
21. Click **[Save Series]**.
22. Repeat steps 16 to 20 for third and any additional stations. Make series description and off-set changes, as necessary.
23. Select the first station in Rx Manager labeled “Top Loc”.
24. Click **[Prepare to Scan]**.
25. Click **[Auto Prescan]**.
26. Give patient breathing instructions.
27. Click **[Scan]**.
28. Repeat steps 23 to 26 for each localizer scan.

12. Enter the **Number of Slices** into the text box.
    - You can enter only an odd number of slices, for example 1, 3, 5, or 9.
    - It is recommended you not enter more than three slices. This ensures scan times are kept short for breath holding techniques.
13. Enter the remaining imaging parameters.
    - Choose a FOV to cover desired anatomy. The recommended FOV is 44.
    - Enter the slice thickness and spacing.
    - Enter matrix and NEX values. Typically use a 256 Frequency value, 128 Phase value, and 2 NEX.
14. Click **[Save Series]**.
    - This closes the view/edit mode and changes series status to RXD.
15. Select the localizer in the Rx Manager, right-click, and select **Copy** from the pull-down menu.
    - Copy/paste the first series twice, so you can View/Edit the localizer and change the Center FOV in the S/I direction to the desired offset.
16. With the cursor still in the Rx Manager, select **Paste**, then **Paste** again.
    - Selecting **Paste** twice deposits two localizer prescriptions in the Rx Manager.
    - Select **Paste** for as many stations as you will prescribe for the scan Multi-station prescription.
17. Select the second localizer in the Rx Manager and click **[View Edit]**.
18. Change the description of the series.
    - You may choose to enter any description. The suggested description is “Mid Loc”.
    - This allows you to distinguish the localized meta-series at a glance within the Rx Manager area.
19. Change coil type, if necessary.
    - You must change your coil type if you are using the PV coil.

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20. Change Center FOV off-set to **`I420`**.
    - Establishes second station center FOV.
    - Only use the suggested inferior off-set if your patient is in the PV coil.
    - If you choose not to use the suggested off-set, when scanning with the body coil, enter desired off-set now.
21. Click **[Save Series]**.
    - Closes the view/edit mode and changes series status to RXD.
22. Repeat steps 16 to 20 for third and any additional stations. Make series description and off-set changes, as necessary.
    - You may choose to enter any description. The suggested third station series description is “Bot Loc”.
    - Suggested off-set for third station is I840.
23. Select the first station in Rx Manager labeled “Top Loc”.
    - Highlights the first series.
24. Click **[Prepare to Scan]**.
25. Click **[Auto Prescan]**.
    - This prescans the localizer series.
26. Give patient breathing instructions.
    - Instruct the patient to suspend breathing until the table starts to move to second station.
    - If your patient has difficulty suspending their breath, follow your facility’s guidelines on breath-holding techniques.
27. Click **[Scan]**.
    - Initiates the first series acquisition.

NOTE: Only the highlighted series is scanned.

28. Repeat steps 23 to 26 for each localizer scan.
    - Advance the table as needed.

NOTE: When acquiring a SmartStep scan, Auto Scan is automatically turned off after the 3-Plane Localizer is acquired. You must manually start the next acquisition.

Set up the Scan Parameters

Quick Steps: Set up the Scan Parameters

1. Click **[New Series]**.
2. Enter the **Patient Position** information.
3. Change coil type, if necessary.
4. Enter **3D Top** in the **Series Description** text box.
5. Select **Plane > Oblique**.
6. Select **Mode > 3D**.
7. Select **Fast TOF SPGR** in the Pulse Sequence window.
8. Click **[Accept]**.
9. Select **Grad Mode > Whole**, if applicable.
10. Select **Multi Station**, **ZIPx2**, **ZIP 512**, and **Fluoro Trigger** in the Imaging Options window.
11. Click **[Accept]**.
12. Enter all remaining imaging parameters.
13. Select **Contrast**.
14. Enter in the correct amount of contrast being administered.
15. Click the **Vascular Screen** icon.
16. Select **On** for collapsed image.
17. Enter **0** for the number of projections.

Use this procedure following Patient Preparation and Scan the Localizer Series portions of the examination. The steps provided give you instructions on how to set up the scan parameters of a SmartStep series with Fluoro Trigger.

1. Click **[New Series]**.
   - Opens up a new blank scan prescription.
2. Enter the **Patient Position** information.
   - Recommended you use the PV coil, if available.
   - Patient entry must match entry of localizer series.
3. Change the coil type, if necessary.
   - Recommended you use the PV coil, if available.
4. Enter **3D Top** in **Series Description** text box.
   - Located in the Patient Position area.
5. Select **Plane > Oblique**.
   - Located in the Imaging Parameters area.
6. Select **Mode > 3D**.
   - Located in the Imaging Parameters area.
7. Select **Fast TOF SPGR** in the Pulse Sequence window.
   - Refer to the Fast Time of Flight Pulse Sequences chapter in Volume 2 for pulse sequence specifications.
8. Click **[Accept]**.
   - This registers the pulse sequence for your acquisition.
9. Select **Grad Mode > Whole**, if applicable.
   - The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.
10. Select **Multi Station**, **ZIPx2**, **ZIP 512**, and **Fluoro Trigger** in the Imaging Options window.
    - All imaging options listed above can be used, but are not required, with the exception of Multi Station. Multi Station must be selected in order to perform a Bolus Chasing procedure.
    - Selecting ZIP 1024 may require too much system memory and is not recommended.

NOTE: SmartPrep can be selected in place of the Fluoro Trigger Imaging Option. These options cannot be used at the same time. You can only select one.

Refer to the Bolus Triggering chapter in this guide for steps on using SmartPrep.

11. Click **[Accept]**.
    - This registers the imaging options into your current acquisition.
12. Enter all remaining imaging parameters.
    - Suggested parameters are: Minimum TE, 45° Flip Angle, 46-48 FOV, 3 slice thickness, 32 to 40 locations, 256x128 matrix, 0.8 Phase FOV, 1 NEX, and turn AutoShim on.
13. Select **Contrast**.
    - **Amnt** and the **Agent** text box become active.
14. Enter in the correct amount of contrast being administered.
    - The correct amount of contrast is needed to establish an accurate threshold for the patient.
15. Click the **Vascular Screen** icon.
    - Located in the Additional Parameters area.
16. Select **On** for collapsed image.
    - This allows your system to reconstruct a collapsed image of the scanned areas.
17. Enter **0** for the number of projections.
    - This saves reconstruction time. Images can be post processed later for projection images.

NOTE: Refer to Interactive Vascular Imaging chapter in Volume 5 for information on creating projection images.

18. Click **[Accept]**.
    - This registers the Vascular selections into the current acquisition.
19. Click the **User CVs Screen** icon.
    - Located in the Additional Parameters area.
20. Enter the **Number of Stations** you want in the text box.
    - Up to four stations can be entered.

Quick Steps: Set up the Scan Parameters cont.

18. Click **[Accept]**.
19. Click the **User CVs Screen** icon.
20. Enter the **Number of Stations** you want in the text box.
21. Enter the **Max. monitor period** in the text box, if necessary.
22. Enter the **Image acq. delay** in the text box.
23. Turn on a k-space filling option.
24. Turn on Mask and/or Venous acquisition options (optional).
25. Turn on or off any other desired options, on the **User CVs Screen**.
26. Click **[Accept]**.

21. Enter the **Max. monitor period** in the text box, if necessary.
    - This option is only available if the SmartPrep Imaging Option was selected.
    - It is recommended you use a 50 second delay. This allows sufficient time for the system to detect the bolus.
22. Enter the **Image acq. delay** in the text box.
    - This text box value should reflect adequate time to give patient breathing instructions.
    - A 5 to 8 second delay is recommended.
23. Turn on a k-space filling option.
    - You can only turn on one k-space filling option.
      - Top station = Centric filling
      - Middle Station = Centric filling
      - Bottom and any remaining stations = Elliptical Centric filling
    - Refer to the k-space section of this chapter for additional information on the k-space filling options.
24. Turn on Mask and/or Venous acquisition options (optional).
    - Refer to the Acquisition Type section of this chapter for additional information on Mask and Venous acquisitions.

NOTE: SmartPrep or Fluoro Trigger Imaging Options are only present in the first station of the Arterial Acquisition meta-series.

It is recommended a Mask Acquisition is acquired whenever performing this type of scan. This ensures correct volume placement and helps to improve image quality when subtraction post processing techniques are used.

25. Turn on or off any other desired options, on the **User CVs Screen**.
    - FAT SAT must be selected prior to choosing SPECIAL on the screen.

NOTE: SPECIAL can not be used with elliptic centric or reverse elliptic k-space filling.

26. Click **[Accept]**.
    - This registers the User CVs into the current acquisition.

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Set up the Graphic Parameters

Use this procedure following Patient Preparation, Scan the Localizer Series, and Set Up of Scan Parameters portions of the examination. The steps provided give you instructions on how to set up the graphic parameters of a SmartStep series.

1. Click the **Graphic Rx** icon.
   - Located in the Additional Parameters area.
2. Click **[Select Series]**.
3. Select the **Top Loc** series.
   - This is your first station of the localizer meta-series.
4. Click **[OK]**.
5. Place the cursor over the desired localizer image and press the **Shift** key and click to deposit your 3D imaging volume.
   - Adjust angle and the left-right, anterior-posterior, and center locations to insure proper coverage of anatomy.

NOTE: Be careful to keep the center FOV "tick" mark at I/S 0 mm, which is represented by the horizontal reference line.

6. Click **[Accept]**.
   - This registers the graphic options into your current acquisition.
7. Click **[Save Series]**.
   - Deposits meta-series in the Rx Manager.
8. Double-click the next station in the meta-series.
   - Opens second series into view/edit mode.
9. Enter **`3D Mid`** in **Series Description** text box.
   - You may choose to enter any description. The suggested description is "3D Mid".
   - This allows you to distinguish the localized meta-series at a glance within the Rx Manager.
10. Change coil type, if necessary.
    - You must change coil type if you are using the PV coil.

Quick Steps: Set Up the Graphic Parameters

1. Click the **Graphic Rx** icon.
2. Click **[Select Series]**.
3. Select the **Top Loc** series.
4. Click **[OK]**.
5. Place the cursor over the desired localizer image and press the **Shift** key and click to deposit your 3D imaging volume.
6. Click **[Accept]**.
7. Click **[Save Series]**.
8. Double-click the next station in the meta-series.
9. Enter **`3D Mid`** in **Series Description** text box.
10. Change coil type, if necessary.
11. Click the **User CVs Screen** icon to change your k-space filling option.
12. Click **[Accept]**.
13. Click the **Graphic Rx** icon.
14. Click **[Select Series]**.
15. Select the **Mid Loc** series.
16. Click **[OK]**.

Quick Steps: Set up the Graphic Parameters

17. Place the cursor over the desired localizer image and press the **Shift** key and click to deposit your 3D imaging volume.
18. Click **[Accept]**.
19. Click **[Save Series]**.
20. Repeat steps 8 to 19 for all remaining stations.

11. Click the **User CVs Screen** icon to change your k-space filling option.
    - It is recommended you change your filling option for each station. By doing so you improve your probability of catching the bolus at each station.
      - Top station = Centric filling
      - Middle Station = Centric filling
      - Bottom and any remaining stations = Elliptical Centric filling
12. Click **[Accept]**.
    - This registers your User CV selections.
13. Click the **Graphic Rx** icon.
    - Located in the Additional Parameters area.
14. Click **[Select Series]**.
15. Select the **Mid Loc** series.
    - This is the second station of the localizer meta-series.
16. Click **[OK]**.
    - This registers your series selection.
17. Place the cursor over the desired localizer image and press the **Shift** key and click to deposit your 3D imaging volume.
    - Adjust angle and the left-right, anterior-posterior, and center locations to insure proper coverage of anatomy.
18. Click **[Accept]**.
    - This registers the graphic options into your current acquisition.
19. Click **[Save Series]**.
    - This registers the graphic options into your current acquisition.
20. Repeat steps 8 to 19 for all remaining stations.
    - Change third station series description to **`3D Bot`**.
    - On the User CV window, first deselect Centric by changing it to 0.00, then turn Elliptical Centric on by changing it to 1.00.

Scan the SmartStep Series

Use this procedure following Patient Preparation, Scan the Localizer Series, Set Up of Scan Parameters and Set Up of Graphic Parameters portions of the examination. The steps provided give you instructions on how to scan the SmartStep series using the Fluoro Trigger Imaging Option.

NOTE: Refer to the Bolus Triggering chapter in this guide for using the SmartPrep Imaging Option.

1. Select the **3D Bot** series.
   - Located in the Rx Manager area.
2. Click **[Prepare to Scan]**.
3. Click **[Prescan All]**.
   - This prescans all stations in the meta-series from bottom to top.
   - All series prescanned displays PSCD in the status area of the Rx Manager.
4. Skip to step 7 if **NOT** performing a Mask series. Select the first station of Mask meta-series.
   - If you prescribed a Mask meta-series, the cursor should highlight PSCD M/1.

NOTE: You can highlight any series you want to start scanning from. For example, if the patient is claustrophobic and you decide to skip the mask series, place the cursor on the first station of the arterial series.

5. Click **[Prepare to Scan]**.
   - This downloads the acquisition and moves the table to it's starting position.
6. Click **[AutoStep]**.
   - If you have entered a delay before the acquisition, the clock counts down the delay time. This allows you to give breathing instructions to your patient.
   - Initiates the first highlighted meta-series acquisition.
     - All stations within the Mask meta-series are scanned from top to bottom.

Quick Steps: Scan the SmartStep Series

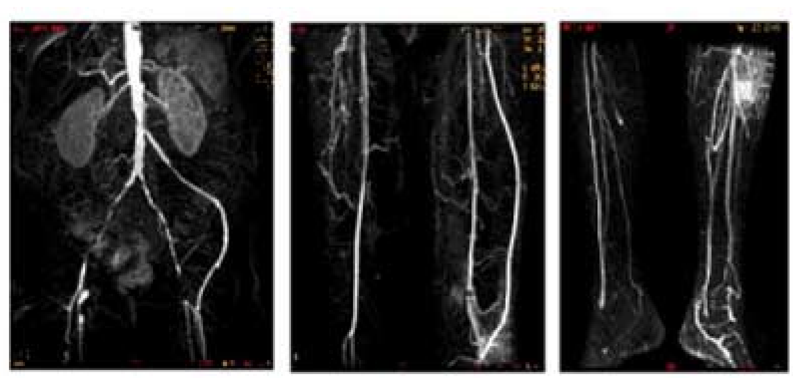
1. Select the **3D Bot** series.
2. Click **[Prepare to Scan]**.
3. Click **[Prescan All]**.
4. Skip to step 7 if **NOT** performing a Mask series. Select the first station of Mask meta-series.
5. Click **[Prepare to Scan]**.
6. Click **[AutoStep]**.
7. Select the first station of the Arterial meta-series.
8. Click **[Prepare to Scan]**.
9. Click **[AutoStep]**.
10. Make adjustments to the fluoro triggered image to ensure a mid-line slice of the vessel.
11. Click **[Go3D]**, once bolus fills the vessel and provide your patient with breathing instructions.

NOTE: The system stops after all the Mask meta-series are acquired. This allows you to prepare for the contrast injection.

7. Select the first station of the Arterial meta-series.
   - This highlights this series and prepares it for downloading.
   - If no mask meta-series was prescribed, the cursor should highlight PSCD A/1.
8. Click **[Prepare to Scan]**.
   - This downloads the acquisition and moves the table to it's starting position.
9. Click **[AutoStep]**.
   - Initiates the first highlighted meta-series acquisition.
   - The system switches to the Fluoro Trigger mode.
10. Make adjustments to the fluoro triggered image to ensure a mid-line slice of the vessel.
    - Refer to the Real Time Imaging chapter in this guide for additional information on options seen on the FT MRA mode screen.
11. Click **[Go3D]**, once the bolus fills the vessel and provide your patient with breathing instructions.
    - This triggers the scan mode of the Arterial acquisition. All series in the meta-series are scanned from top to bottom.
    - The Venous meta-series is acquired from bottom to top.

NOTE: Refer to the Bolus Triggering chapter for additional information on Fluoro Trigger.

3D Top Series 3D Mid Series 3D Bot Series



Copy and Paste a SmartStep Series

The Copy and Paste function allows you to repeat a scan prescription that was already listed in the Rx Manager. Use this procedure to copy and paste a SmartStep series.

1. Select the first station of the arterial series.
   - The series highlights in the Rx Manager.
2. Right-click and drag to select **Copy**.
   - This copies the arterial series.
3. Select the first station of the venous series.
   - The series highlights in the Rx Manager.
   - The copied series is placed immediately below the selected (highlighted) series.
4. Right-click and drag to select **Paste**.
   - This places the arterial series at the bottom of the list in the Rx Manager.
5. Prescan the pasted series.
   - This places the mask and venous series appropriately in the Rx Manager.
6. Proceed with scanning as usual.

Quick Steps: Copy and Paste a SmartStep Series

1. Select the first station of the arterial series.
2. Right-click and drag to select **Copy**.
3. Select the first station of the venous series.
4. Right-click and drag to select **Paste**.
5. Prescan the pasted series.
6. Proceed with scanning as usual.

Scan using the GE Saved SmartStep Protocol

Quick Steps: Scan using the GE Saved SmartStep Protocol

1. Select the **Abdomen/Lumbar A.7 - 3 Station SmartStep FTr PV array** protocol from the GE Protocol list.
2. Scan the desired localizer acquisitions.
3. Set up the top series for scanning.
4. Set up the middle series for scanning.
5. Set up the bottom series for scanning.
6. Select the **3D Bot** series.
7. Click **[Prepare to Scan]**.
8. Click **[Prescan All]**.
9. Select the **M Top** series.
10. Click **[Prepare to Scan]**.
11. Click **[AutoStep]** to scan the Mask meta-series.
12. Select the **A Top** series in the Rx Manager.
13. Click **[Prepare to Scan]**.
14. Click **[AutoStep]** to initiate the meta-series.
15. Click **[Go 3D]** once the bolus fills the vessel and provide your patient with breathing instructions.

Use this procedure to perform a SmartStep scan with the Fluoro Trigger option using the GE saved protocol. The GE saved protocol allows you to select one of two localizers and acquires a three-station meta-series.

1. Select the **Abdomen/Lumbar A.7 - 3 Station SmartStep FTr PV array** protocol from the GE Protocol list.
   - There are three other SmartStep protocols in the Abdomen/Lumbar library:
     – A.6- 3-Station SmartStep SPrep PV Array
     – A.8- 3-Station SmartStep Sprep-Body Coil
     – A.9- 3-Station SmartStep FTr-Body Coil
2. Scan the desired localizer acquisitions.
   - Select either the 3-Plane Localizer or the TOF localizer.
3. Set up the top series for scanning.
   a) Double-click the top station in the meta-series.
   b) Click the **Graphic Rx** icon.
   c) Click **[Select Series]**.
   d) Select the **Top Loc** series.
   e) Click **[OK]**.
   f) Place the cursor over the desired localizer image and press the **Shift** key and click to deposit your 3D imaging volume.
   g) Adjust the angle and position of the 3D volume.
   h) Click **[Accept]**.
   i) Click **[Save Series]**.

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4. Set up the middle series for scanning.
   a) Double-click the middle station in the meta-series.
   b) Click the **Graphic Rx** icon.
   c) Click **[Select Series]**.
   d) Select the **Mid Loc** series.
   e) Click **[OK]**.
   f) Place the cursor over the desired localizer image and press the **Shift** key and click to deposit your 3D imaging volume.
   g) Adjust the angle and position of the 3D volume.
   h) Click **[Accept]**.
   i) Click **[Save Series]**.
5. Set up the bottom series for scanning.
   a) Double-click the bottom station in the meta-series.
   b) Click the **Graphic Rx** icon.
   c) Click **[Select Series]**.
   d) Select the **Mid Loc** series.
   e) Click **[OK]**.
   f) Place the cursor over the desired localizer image and press the **Shift** key and click to deposit your 3D imaging volume.
   g) Adjust the angle and position of the 3D volume.
   h) Click **[Accept]**.
   i) Click **[Save Series]**.
6. Select the **3D Bot** series.
7. Click **[Prepare to Scan]**.
8. Click **[Prescan All]**.
   - The system prescans the meta-series from bottom to top.
9. Select the **M Top** series.
10. Click **[Prepare to Scan]**.
11. Click **[AutoStep]** to scan the Mask meta-series.
    - The Mask meta-series scans from top to bottom.

12. Select the **A Top** series in the Rx Manager.
13. Click **[Prepare to Scan]**.
14. Click **[AutoStep]** to initiate the meta-series.
    - The system switches to Fluoro Trigger mode.
    - The Arterial meta-series scans from top to bottom.
    - The Venous meta-series scans from bottom to top.
15. Click **[Go 3D]** once the bolus fills the vessel and provide your patient with breathing instructions.

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Chapter 17

Bolus Triggering

Introduction

Bolus Triggering is a technique used in imaging vasculature, where a bolus of a contrast medium activates the scan and is sequentially imaged as it moves through the vessels. It can be performed using either of the purchasable options, SmartPrep or Fluoro Triggered Magnetic Resonance Angiography (FT MRA).

This chapter explains the Bolus Triggering process. The focus is on bolus detection and acquisition triggering for contrast-enhanced Magnetic Resonance Angiography (CEMRA). It contains key concepts as well as step-by-step instructions to help you learn how to:

- Set up a FT MRA Series
- Prescribe the Imaging Volume
- Scan the FT MRA Series

In addition, this chapter answers the following questions:

1. What is FT MRA?
2. Which pulse sequences are compatible with FT MRA?
3. Which features are compatible with FT MRA?
4. When would I use the Fluoro Trigger option?

NOTE: This chapter includes new features or enhancements of Bolus Triggering. Refer to the Signa® Infinity with Signa Select™ (ASP2) Learning and Reference Guide (direction #2292263-100) for the SmartPrep bolus triggering technique.

What Do I Need to Know About...

This section presents the concepts necessary to successfully complete the Bolus Triggering process. Specifically, you need to understand:

- Fluoro Triggered MRA Basics
  - Supported Features
- Applications

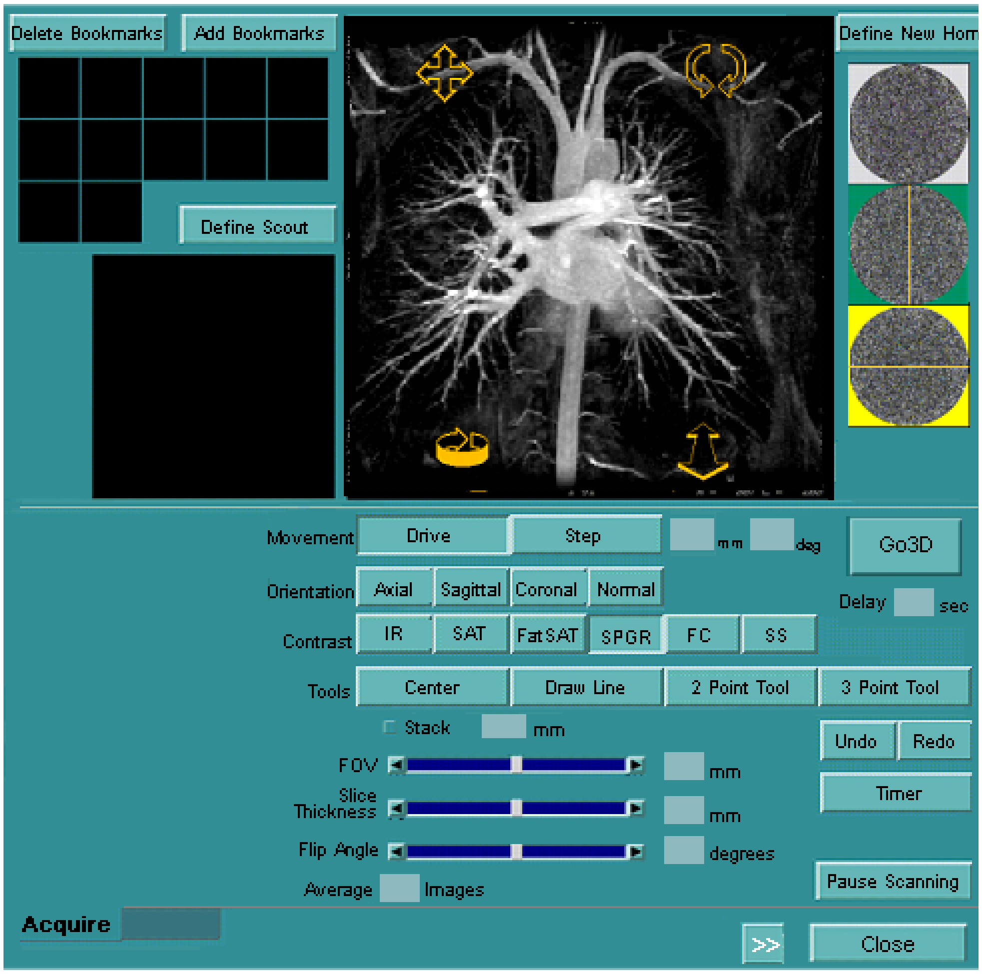
Fluoro Triggered MRA Basics

Fluoro Triggered Magnetic Resonance Angiography (FT MRA) is a technique that uses a thick slab, two-dimensional (2D) real time acquisition and reconstruction to monitor a region of interest. FT MRA is used to detect the arrival of a contrast bolus. This feature allows you to trigger an elliptic-centric view ordered acquisition of a three-dimensional (3D) volume of interest once a patient’s vessels have sufficiently enhanced. The 3D acquisition is perfectly synchronized to the peak concentration of contrast in the vessels. FT MRA images are annotated “FTr” in the lower left hand corner.

Elliptic-centric k-space filling may be used with a FT MRA sequence. This option is located on the User CVs screen, accessed in the Additional Parameters area. Refer to the Elliptic-centric section of this chapter for additional information regarding this type of k-space filling.

Unlike SmartPrep, FT MRA relies on you to trigger the acquisition, once the bolus is detected. It incorporates Real Time Imaging so the contrast is visually seen within the vessel before the acquisition is started. Once the acquisition is downloaded and the **[Scan]** button is clicked, you are in the FT MRA mode (Figure 17-1). This window looks and operates much like the Real Time Imaging Acquire tab.

Figure 17-1 FT MRA Mode



There are five main differences between the FT MRA imaging mode and the Real Time imaging mode Acquire tabs.

- The **[Pause When Full]** button is no longer available.
- The **[Save Image]** button is no longer available.
- The **Review** tab is no longer selectable.
- A **Delay** text box appears, allowing you to enter a system delay value in seconds. The value defaults to the delay set by the prescribed acquisition. This value can be changed and a new value can be typed in. The delay period is the time after the **[Go 3D]** button is clicked and the scan actually starts.
- The **[Go3D]** button appears, allowing you to initiate the prescribed acquisition. This button remains active when real time scanning is in progress. If the **[Pause Scanning]** button is selected, the **[Go3D]** button becomes inactive.

NOTE: Refer to the Real Time Imaging chapter in this guide for explanation of other options present on the Acquire tab.

Supported Features

The Fluoro Trigger Imaging Option is compatible with the 3D imaging mode and the following pulse sequences:

- Fast Time of Flight (TOF) Gradient Echo (GRE) and SPoiled Gradient Echo (SPGR)
- Fast GRE and SPGR

In addition, FT MRA is compatible with the features listed in Table 17-1.

Table 17-1 Fluoro Trigger Compatibility

Compatible	Not Compatible
ZIP 1024	Flow Compensation
ZIP 512	POMP
ZIP x2	Square Pixels
ZIP x4	Respiratory Compensation
Multi Station	Magnetization Transfer
Variable Bandwidth	Cardiac Gating/Triggering
No Phase Wrap	Tailored RF
Extended Dynamic Range	DE Prepared
Multi Phase	Full Echo Train
Spatial Saturation	SmartPrep
Fat/Water Suppression	T2 Prep
	Phase Sensitive
	Surface Coil Intensity Correction
	Sequential
	Classic
	Respiratory Gating/Triggering
	IR Prepared
	Cardiac Compensation
	Blood Suppression
	Real Time
	Spectral Spatial RF

NEX and Fat Saturation

During the real time imaging portion of the FT MRA acquisition, the NEX is defaulted to one and Fat SAT is turned off to improve frame rate. Once the 3D acquisition starts, Fat SAT is turned back on and the NEX you prescribed is used.

Saturation Bands

To improve the contrast visualization during a FT MRA acquisition, you can prescribe explicit SAT bands during real time imaging along the S/I direction by setting User Control Variable (CV) 19 to 0. This selection places the SAT bands at the edge of the scan FOV during the real time scan. The default SAT band is 8 cm in the S/I direction; 7 cm is outside the FOV and 1 cm is inside the FOV.

For axial planes, the concatenated SAT is a better choice, as it is closer to the imaging slice. You can select a concatenated SAT by setting User CV 19 to 1. This selection places the SAT bands parallel to the slice during the real time scan and allows them to move with the slice. This is useful for monitoring contrast in the axial plane during carotid and liver imaging. For body MRA, coronal or sagittal planes are often used where a fixed S/I SAT is appropriate.

The User CV selection only determines the location of the SAT bands. You also need to click the **[SAT]** button on the Real Time Imaging Acquire tab to turn SATs on for imaging.

Applications

Use FT MRA when SmartPrep is not optimal,e.g., when a patient has slow cardiac output or if delayed imaging enhancement is desired. FT MRA is also recommended for performing carotids and T1 post contrast liver examinations.

How Do I...

This section provides the step-by-step instructions for bolus triggering. Specifically, it describes how to:

- Set up a FT MRA Series
- Prescribe the Imaging Volume
- Scan the FT MRA Series

Set up a FT MRA Series

Use this procedure to setup a FT MRA series. By using FT MRA, the system allows you to scan the prescribed acquisition once contrast has been detected by you. This make bolus detection easier, if use of SmartPrep is not available or optimal.

You should already know how to set up a protocol for your system; only a brief review is explained. The rest of the procedure guides you through the FT MRA setup process.

1. Select the appropriate coil.
   - Refer to the Gradient, Shim and Imaging Coil chapter in Volume 1 for suggested coil positioning.
2. Position the patient comfortably and immobilize the area of interest with sponges.
3. As directed by physician, set up the patient IV catheter and prepare the power injector (optional).
   - Follow your physician's or facility's guidelines.
4. Landmark the patient.
5. Press **Move to Scan**.
   - This moves the patient to the landmarked location inside the scanner bore.
6. Acquire an appropriate localizer series.
   - Sometimes more than one localizer is needed to make sure proper volume coverage is included.
7. Click **[New Series]**.
8. Click the **Pt. Position** icon.
   - Located on the Scan Desktop.
9. Select **Plane > Oblique**.
   - Located in the Patient Position area.
10. Select **Mode > 3D**.
    - Located in the Patient Position area.

NOTE: You can prescribe a coronal orthogonal plane. Make sure the volume includes the necessary imaging anatomy.

11. Select **Fast TOF GRE** or **Fast TOF SPGR** in the Pulse Sequences window.

Quick Steps: Set up a FT MRA Series

1. Select the appropriate coil.
2. Position the patient comfortably and immobilize the area of interest with sponges.
3. As directed by physician, set up the patient IV catheter and prepare the power injector (optional).
4. Landmark the patient.
5. Press **Move to Scan**.
6. Acquire an appropriate localizer series.
7. Click **[New Series]**.
8. Click the **Pt. Position** icon.
9. Select **Plane > Oblique**.
10. Click **Mode > 3D**.
11. Select **Fast TOF GRE** or **Fast TOF SPGR** in the Pulse Sequences window.
12. Select **Grad Mode > Whole**, if applicable.
13. Select **Fluoro Trigger** in the Imaging Options window.
14. Complete the scan prescription.
15. Click the **User CVs Screen** icon.
16. Complete the **User CVs Screen** parameters.

12. Select **Grad Mode > Whole**, if applicable.
    - The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.
13. Select **Fluoro Trigger** in the Imaging Options window.

NOTE: Select **Multiphase** to capture both the arterial and venous phase. Refer to the Imaging Options chapter in Volume 4 for additional information.

14. Complete the scan prescription.
    a) Select the scan timing parameters to minimize TR and TE.
    b) Select FOV, matrix, and slice thickness to balance spatial resolution and SNR.
    c) Minimize scan time to allow for breath-held acquisitions.

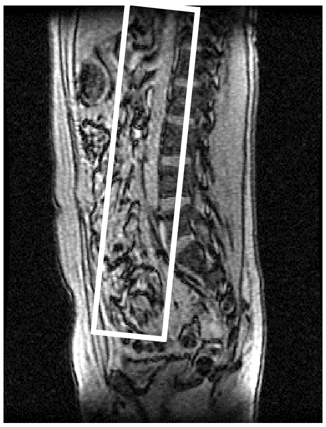
NOTE: Remember to enter the correct contrast dosage. Refer to Threshold section for detailed information.

15. Click the **User CVs Screen** icon.
    - Located in the Additional Parameters area.
16. Complete the **User CVs Screen** parameters.
    a) Expand the delay time.
    b) Set your SAT band choices.
       – Enter **0** for User CV 19 to prescribe explicit SAT bands.
       – Enter **1** for User CV 19 to prescribe a concatenated SAT band.
    c) Set the desired type of k-space filling.

Prescribe the Imaging Volume

Use this procedure to prescribe the FT MRA imaging volume. The set up of the FT MRA series must be done prior to placing the imaging volume.

1. Click the **Graphic Rx** icon.
2. Select an appropriate series and image.
3. Press the **Shift** key and click on the image to place your 3D imaging volume.



Example of an imaging volume placed on a midline slice.

   - A midline slice is best for setting up your imaging volume, unless your patient is off center inside the magnet.

4. Adjust the angle of the volume to ensure proper coverage of anatomy.
   - The angle can only be adjusted in the oblique plane.
5. Click **[Fallback]**, if necessary.
   - This allows your imaging volume center to be set at R0.
   - Do not fallback if you are using a projection image of a 2DTOF for the localizer.
6. Click **[Accept]**.
   - Closes the Graphic Rx screen.
7. Click **[Save Series]**.
   - Closes the scan prescription screen.
   - Accepts the scan prescription.
   - Saves it in the Rx Manager as RXD.

Quick Steps: Prescribe the Imaging Volume

1. Click the **Graphic Rx** icon.
2. Select an appropriate series and image.
3. Press the **Shift** key and click on the image to place your 3D imaging volume.
4. Adjust the angle of the volume to ensure proper coverage of anatomy.
5. Click **[Fallback]**, if necessary.
6. Click **[Accept]**.
7. Click **[Save Series]**.

Scan the FT MRA Series

Quick Steps: Scan the FT MRA Series

1. Click **[Prepare to Scan]**.
2. Click **[Auto Prescan]**.
3. Click **[Scan]**.
4. Adjust the real time image.
5. Enter Delay value, if necessary.
6. Begin administering contrast to the patient.
7. Watch for the bolus on the FT MRA viewer.
8. Click **[Go3D]**, once bolus fills vessel.

Use this procedure to scan the FT MRA series. The set up of the FT MRA series and the prescription of the imaging volume must be done prior to scanning the series.

1. Click **[Prepare to Scan]**.
2. Click **[Auto Prescan]**.
3. Click **[Scan]**.
   - Initiates the acquisition in the FT MRA mode.
4. Adjust the real time image.
   - Use the real time controls.
   - Visualize the best possible midline slice of the vessel.
5. Enter a delay value in the **Delay** text box, if necessary.
   - The delay time should be sufficient enough to allow the patient time to hold his or her breath.
   - Recommended delay times are 5 seconds or less.
6. Begin administering contrast to the patient.
   - The amount of contrast should be determined by your physician or facility personnel.
   - Contrast can be administered by either a power injector or hand bolus.
7. Watch for the bolus on the FT MRA viewer.
8. Click **[Go3D]**, once bolus fills vessel.
   - This enters the quiet delay period. The count-down can be observed from the PC monitor or from the magnet cover.
   - Once the delay timer reaches 1 second, the system automatically switches into scanning mode.
   - The FT MRA screen disappears and the Scan Desktop is again displayed.
   - Once the system switches into scanning mode, an audible switch of the gradients can be heard.

Chapter 18

Imaging Real Time

Introduction

*i*Drive™ Pro Plus is an optional software package that provides a flexible environment for imaging Real Time Cardiac Acquisitions (RTCAs). *i*Drive Pro Plus can be used to interactively manipulate the scan plane and image contrast. Images you acquire with *i*Drive Pro Plus can be used to prescribe scan planes and locations for other series in the exam once the correct plane and locations have been determined.

This chapter explains how to image real time with *i*Drive Pro Plus. It provides key concepts regarding the acquisition, tools, image review options, and application tips on where to use interactive imaging. This chapter also contains the step-by-step instructions to help you learn how to:

- Prescribe a real time sequence
- Use the Movement tools
  - Drive through an image volume
  - Step through an image volume
- Manage Home Images
  - Define a scan plane
  - Define new Home Images
- Manage Bookmarks
  - Create a Bookmark
  - Recall a Bookmark
  - Enlarge a thumbnail and apply for scanning

- Use the Graphic tools
  - Change the FOV center
  - Draw a line in the Main Viewer
  - Draw a line in the Scout Viewer
  - Draw a line in the Multi-slice Mode
  - Apply the 2 Point tool
  - Apply the 3 Point tool
- Review real time images
  - Playback images
  - Save images

In addition, this chapter answers the following questions:

1. What pulse sequences can I use with *i*Drive Pro Plus?
2. What factors affect frame rate?
3. What tools are available on the *i*Drive Pro Plus Acquire tab?
4. What are Home Images?
5. What are Bookmarks?
6. What tools are available on the *i*Drive Pro Plus Review tab?
7. What are the applications for imaging with *i*Drive Pro Plus?

What Do I Need to Know About...

This section presents the concepts necessary to successfully complete imaging real time process with *i*Drive Pro Plus. Specifically, you need to understand:

- Real Time Imaging Overview
- Real Time Imaging Basics
  - Frame Rate
  - Image Acquisition
- Acquire Tab
  - Home Images
  - Bookmarks
  - Image Buffer
  - Multi-slice Mode
- Acquire Tab Tools
  - Movement Tools
  - Orientation Tools
  - Contrast Tools
  - Graphic Tools
  - Parameter Tools
  - Graphic Prescription Tools
- Review Tab
  - Review Images
  - Image Slider
- Applications
- Troubleshooting Tips

Real Time Imaging Overview

Real time imaging allows you to navigate through your patient's anatomy for rapid visualization and monitoring of temporal physiological events. This includes, but is not limited to, patient breathing, kinematic studies, and bolus activity. Real time images can also be used for directly prescribing scan planes of other series in the exam. The Real Time Imaging Option allows for Real Time Cardiac Acquisitions (RTCAs) with the *i*Drive Pro Plus optional software package.

Real Time Imaging Basics

*i*Drive Pro Plus is an optional software package that allows you to image RTCAs with greater flexibility. You can use *i*Drive Pro Plus to interactively manipulate the scan plane and image contrast. Images you acquire with *i*Drive Pro Plus can be used to prescribe scan planes and locations for other series in the exam once the correct plane and locations have been determined.

RTCAs can be acquired with the following pulse sequences:

- Fast Gradient Echo (FGRE)
- Fast Spoiled Gradient Echo (FSPGR)
- Fast Gradient Echo-Echo Train (FGRET)
- Spiral GRE
- Spiral SPGR

Frame Rate

The Advisory panel of the Scan Rx desktop displays the number of images acquired in one second based on the current series parameters. This is shown in the frames per second (FPS) status area. The gradient platform and array processor configuration affect the maximum number of images or frames per second that can be generated. Another factor affecting the frame rate is the number of receive coils. The use of a phased array coil may decrease the frame rate as compared to a single receive coil.

When imaging with *i*Drive Pro Plus, the phase and frequency matrix selections are the predominant factors affecting the FPS in non-Spiral acquisitions. In Spiral scans, the number of arms and number of points are the predominant factors affecting the FPS.

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Image Acquisition

To use the features of the Real Time Imaging Option, you must first prescribe a single-slice series at the Scan Rx desktop. This series must have Real Time selected at the Imaging Options window. The real time series can be saved as a stand-alone protocol or as part of a larger protocol with an existing batch series. It can be cut, copied or pasted using the Rx Manager tools and can be used in a protocol that is being automatically scanned.

When you start the scan, there is a slight pause (less than six seconds) before the system is ready to display the images. The tools and functions available on the Acquire tab help you manipulate the scan plane and contrast of the images. These actions are a combination of button selections and cursor manipulations on the image screen itself.

When the real time application is launched, Archive, Network, and Filming operations are automatically paused by the system. However, there is **no** notification of the pause status. These processes automatically resume when the real time application is closed.

Images acquired real time are not automatically saved to the system disk. The **[Save Image]** button on the Acquire tab saves a single image to the disk when that image is displayed in the Acquire tab Main Viewer.

Data acquisition can be paused by clicking the **[Pause Scanning]** button on the Acquire tab or by pressing the **Pause Scan** hard key on the keyboard. If the keyboard is used to pause scanning, the Acquire tab **[Pause Scanning]** button appears depressed. Scanning can be initiated again with the **Start Scan** hard key or by selecting the **[Pause Scanning]** button on the Acquire tab. When scanning is paused, most of the Acquire tab controls become unavailable.

Acquire Tab

The RTCA Acquire tab (Figure 18-1) displays when the **[Scan]** button is selected from the Scan Rx desktop in a real time prescription with *i*Drive Pro Plus. Data acquisition begins and three Home Images are acquired, one image in each orthogonal plane.

Figure 18-1 RTCA Acquire Tab

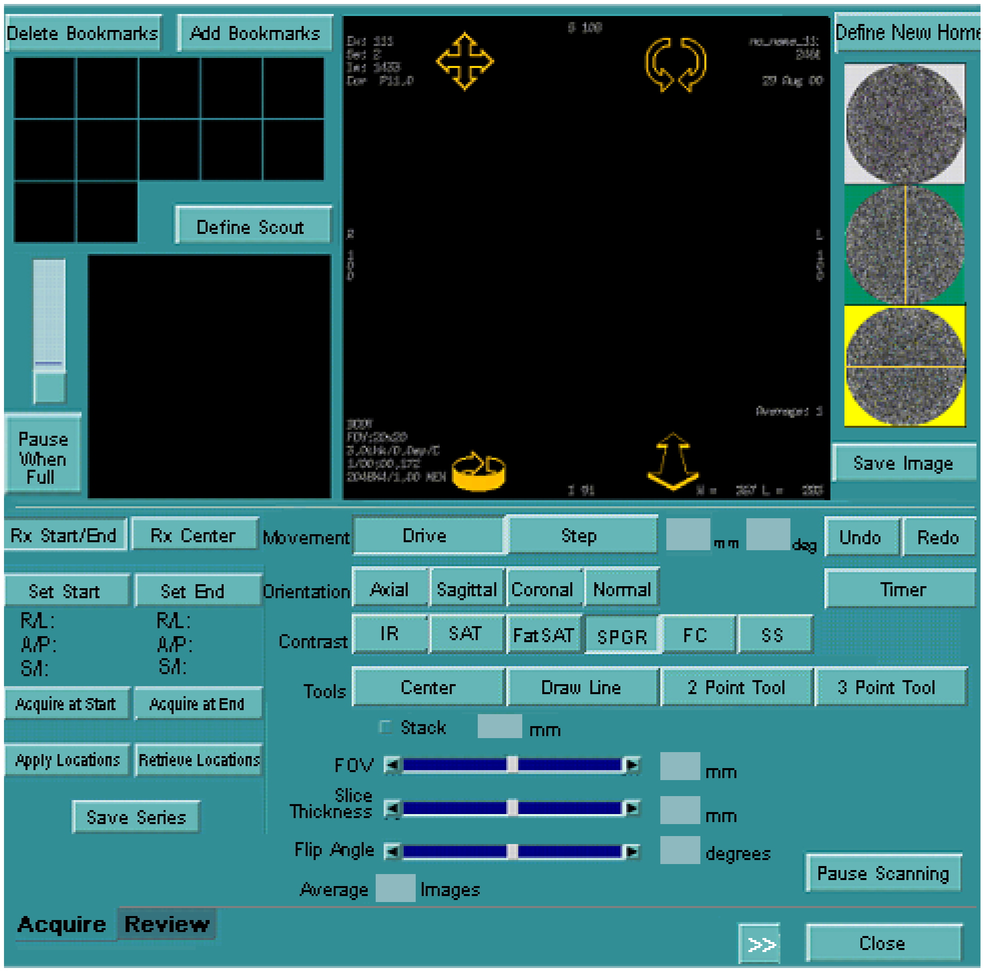

Table 18-1 provides a description and acceptable values for each selection on the Acquire tab for RTCAs imaging with *i*Drive Pro Plus.

Table 18-1 RTCA Acquire Tab Selections and Descriptions

Selection	Description
[Delete Bookmarks]	Deletes all bookmark thumbnails currently displayed. Individual bookmarks cannot be deleted.
[Add Bookmarks]	Saves the plane, location, and image contrast of the current image as a bookmark thumbnail for later recall. Up to 12 images can be bookmarked.
[Define Scout]	Copies the image in the Main Viewer to the Scout Viewer (the viewer directly under the **[Define Scout]** button).

Selection	Description (Continued)
Scout Viewer	Contains a static 256x256 image that can be used with the Draw Line tool to prescribe orthogonal real time image planes. This viewer is empty when real time scanning begins.
[Pause When Full]	Pauses the real time data acquisition automatically when the real time image buffer is full. The progress bar provides a graphic display of the image buffer capacity.
Main Viewer	Displays the real time images as real time data acquisition is taking place. This image is also used with the Movement and Graphic Tools for defining new scan planes.
[GO]	Becomes visible on the real time image when the Draw Line tool is selected. It is used to initiate the scan plane change when a line is drawn on the real time image. Alternatively, right-click anywhere on the image to initiate data acquisition.
[Define New Home]	Acquires new home images. The new home images are acquired in three orthogonal planes based on the real time image currently displayed in the Main Viewer.
[Save Image]	Saves the current real time image to the system disk and lists the image in the Browser. Saved images can be used in Graphic Rx in subsequent series.
[Rx Start/End]	Displays the IGRx location tools. The IGRx tools are used to save or retrieve locations for defining additional real time and/or non-real time sequences.
[Rx Center]	Displays the IGRx center tools. The IGRx tools are used to save or retrieve locations for defining additional real time and/or non-real time sequences.
[Undo]	Returns the real time image to the state prior to the most recent change, undoing the most recent scan plane or image contrast change. It can also be used if *i*Drive Pro Plus has been exited. Selecting the **[Undo]** button upon re-entering *i*Drive Pro Plus, the last location scanned in the prior real time session will be acquired provided the ID, Landmark and Patient Position have not changed. In Drive mode, it undoes all Drive functions returning the image to its original state before any Drive tools were applied. In the Step mode, it undoes all Step functions returning the image to its original state before any Step tools were applied.
[Redo]	Cancels the most recent Undo operation. The real time image returns to its previous state.

Selection	Description (Continued)
[Timer]	Turns the on-image time display on or off. The on-image timer shows the scan time for a single image. When Timer is on, the scan timer on the PC is set to zero. The timer readout updates with each new image acquired and displayed. It displays the time the image was acquired since the **[Timer]** button was clicked.
Movement	Contains tools used to define the on-image scan plane manipulation features.
Orientation	The scan plane can be quickly returned to any orthogonal orientation, at the current FOV center, by selecting the **[Axial]**, **[Sagittal]**, or **[Coronal]** buttons. The **[Normal]** button adjusts the image to a normal anatomic presentation. The image is presented such that RAS coordinates are in their "normal" positions in the viewer.
Contrast	Contains tools used to adjust image contrast parameters. The contrast tools available are based on the pulse sequence.
Tools	Provides access to the Graphic tools that provide alternate methods used for manipulating the scan plane.
Stack	Enables the Multi-slice mode. The stack values are shown in millimeters in the range of 10 to 100.
FOV	Allows changes in the prescribed FOV by moving the slider or by entering a value in the text box.
Slice Thickness	Allows changes in the prescribed slice thickness by moving the slider or by entering a value in the text box.
Flip Angle	Allows changes in the prescribed flip angle by moving the slider or by entering a value in the text box.
Average	Specifies the number of images to be averaged to create the real time image. This improves the signal-to-noise ratio (SNR), as well as motion averaging. Averaging occurs as long as the real time image location and contrast setting are not changed. A value of 1 effectively means no averaging. The maximum allowable value is 8.
[Swap Phase/Freq]	Toggles on to swap the phase and frequency matrix directions based on the original series prescription. This is not available for Real Time Spiral Imaging.
[Pause Scanning]	Stops real time data acquisition. The Acquire tab remains open. Selecting the **[Pause Scanning]** button again resumes data acquisition.

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Selection	Description (Continued)
[Review]	Pauses scanning and moves the display to the *i*Drive Pro Plus Review tab. The Review tab is used to view and save recently acquired real time images.
Message Area 	Displays all error and warning messages that have been posted throughout the current real time session. Messages displayed are cleared when any action is performed within the user interface. Selecting the double arrows displays a dialog box with a scrollable list of messages that have been displayed for the current real time session.
[Close]	Exits the Acquire tab, stops the current real time session, and returns to the Scan Rx desktop. Once you close *i*Drive, you cannot access images that have not been saved.

Home Images

The three orthogonal images acquired upon initialization of a real time series are displayed in the three vertical viewers along the right side of the Acquire tab Main Viewer (Figure 18-2). These images are called Home Images. The Home Images created are axial, sagittal, and coronal, based on the locations prescribed at the Scan Rx desktop during the real time series prescription. The Home Images are automatically saved to the system disk.

Figure 18-2 Home Images

During the real time session, cut-lines display on the Home Images indicating where the current real time image intersects the Home Images. As the scan plane is manipulated, the cut-lines update to indicate the new scan plane.

Defining a Scan Plane Based on Home Images

The Home Images are essentially a three-plane localizer. They can be used to define an orthogonal scan plane and new Home Images can be defined. You can also use your Home Images to reset your current scan plane. Clicking on any one of the Home Images obtains a real time image in that scan plane.

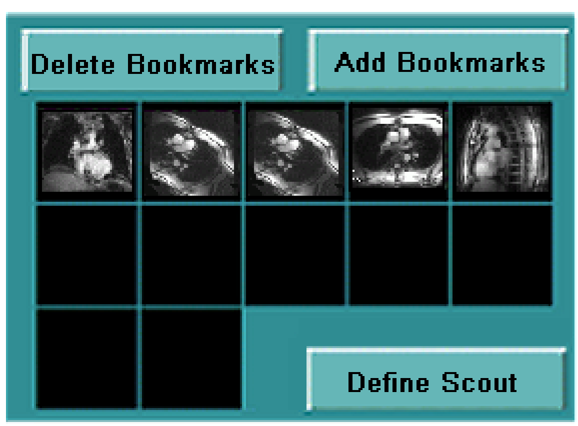
Defining New Home Images

You also have the ability to replace your home images with new images. When you decide that new Home Images are desired at the location of the current real time image, select the **[Define New Home]** button. The first time you define new home images during an acquisition, a message displays informing you that your current home image locations will be replaced by new home images. If this is your intent, click the **[OK]** button. The system then acquires and displays three orthogonal images based on the location of the real time image. This includes the right, anterior, and superior (RAS) offsets of current real time image.

Bookmarks

An image can be bookmarked to recall at a later time. A recall can be performed to obtain the scan plane and image contrast from that image. When an image is bookmarked, it is displayed as a thumbnail image in the Bookmark Viewers (Figure 18-3).

Figure 18-3 RTCA Bookmark Viewers



RTCAs can store up to 12 Bookmarks. A single thumbnail image can be enlarged from a 64x64 to a 128x128 pixel display by leaving the cursor on the image for longer than one second. When you move your cursor off of the enlarged thumbnail image, it immediately returns to its original size. An enlarged thumbnail can be selected for scan by clicking it. This updates the image in the Main Viewer to the contrast and slice view of the Bookmark.

Bookmarks are not automatically saved to the image disk. If a RTCA is exited and re-entered, the Bookmark thumbnails from the prior real time session are saved only if the Patient ID, Landmark, and Patient Position have not changed.

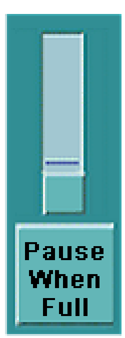
If all thumbnail viewers are filled and the **[Add Bookmarks]** button is clicked, a message posts telling you to right-click on an occupied viewer to replace that thumbnail with the current image. All thumbnail images in RTCAs can be deleted by clicking the **[Delete Bookmarks]** button.

Image Buffer

The Image Buffer holds all of the images acquired with real time. If the buffer is filled and scanning continues, the first images placed into the buffer are deleted to make room for the current real time images using the First In, First Out (FIFO) method. FIFO buffer images are not automatically saved. You can review images in the image buffer and save individual images or an entire range of images. You can also select an image from the buffer and resume scanning at that location. The system automatically pauses scanning once the image buffer fills. Think of the image buffer as fluoroscopy. Nothing is saved unless you “spot film.”

RTCAs imaged with *i*Drive Pro Plus can hold up to 960 real time images. The actual number of images in the buffer depends on the image size of the reconstructed image. For example, an FGRE sequence may allow only 250 images, while Spiral may allow up to 960. These images are held in the real time Image Buffer and the buffer capacity is indicated by the progress bar (Figure 18-4).

Figure 18-4 RTCA Image Buffer Progress Bar



The **[Pause When Full]** button can be toggled on to halt real time data acquisition when the buffer becomes full. This indicates that no images acquired from this point forward are to be discarded. When the number of images acquired equals the capacity of the image buffer, scanning is paused. The progress bar (Figure 18-4) provides a graphic display of the Image Buffer capacity. To clear the buffer, click the **[Pause When Full]** button. The progress bar indicator clears, indicating that the buffer has been reset. When the **[Pause When Full]** button is toggled off, the progress bar is inactive.

When the real time Image Buffer becomes 85% full or greater, the **[Define New Home]** button becomes non-functional when the **[Pause When Full]** button is enabled. If you request new home images to be defined while the buffer is nearing 85% full, the system may not collect the new home images as you requested. In this case, you must empty the Image Buffer before you are able to define new home images.

The arrow button below the Image Buffer progress bar can be used to purge the buffer at any time. Alternatively, the images can be reviewed, saved, and purged from the Review tab.

Note that if the RTCA is closed, the images in the Image Buffer are held in the buffer until a change has been made to the Patient ID, Patient Position, or Landmark. Therefore, if the RTCA is re-entered for the current patient, the real time images from the prior session remain in the Image Buffer.

Multi-Slice Mode

Multi-slice mode can be used with *i*Drive Pro Plus to visualize a multiple-slice, or "stack" acquisition during RTCAs. This may be useful to visualize the start and end locations before applying the locations to a series in the Rx Manager. The Stack check box and the **mm** text box (Figure 18-5) are used in conjunction with the Draw Line tool to use Multi-slice mode.

Figure 18-5 RTCA Multi-slice Mode Enable Area

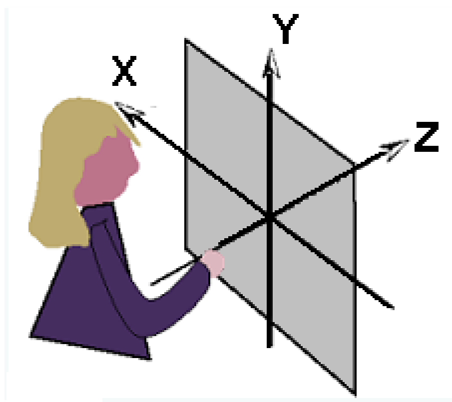
The stack is NOT used to acquire a volume (stack) in *i*Drive Pro Plus; it only designates the stack thickness to use for the Draw Line tool. The range of thickness is 0 to 480 mm. When you change the stack thickness value, the locations are updated on the real time image in the Main Viewport to reflect the new stack thickness entry.

Acquire Tab Tools

The Acquire tab contains tools for you to change the sequence parameters, move the acquisition, change the graphic location, enhance real time image contrast, as well as set up and enable a graphic prescription.

Figure 18-6 displays the orientation of the real time scan plane of the RTCA relative to you and the conventional axis used to describe the real time control tools.

Figure 18-6 Conventional Axis Used to Describe Tools

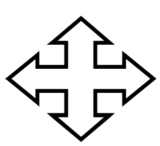


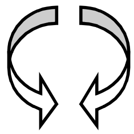
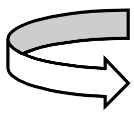
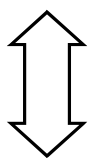
Movement Tools

The scan plane can be manipulated using the Movement tools accessed in both the Drive and Step modes for RTCAs. Each Movement tool is activated by an on-screen (on-image) icon on the real time Main Viewer. These Movement tools enable you to navigate the location of the real time image.

The tool icons are used to access the Movement tools in RTCAs imaged with *i*Drive Pro Plus. When the cursor is moved into one of the four corners of the Main Viewer, the cursor displays the icon associated with that tool accessed in that corner. Table 18-2 illustrates the Movement tools for RTCAs imaged with *i*Drive Pro Plus and provides a description of each.

Table 18-2 RTCA Movement Tools Selections and Descriptions

Movement Tool	Description
Pan 	The Pan cursor is activated by clicking in the upper-left corner. Panning is used to scroll the image in the X and Y directions in the viewer; left and right (X), up and down (Y). The FOV center is changed with no changes to the scan plane obliquity or orientation. When in Step mode, movement occurs in increments based on the value set in the Movement tools text box. This value is displayed in millimeters.

Movement Tool	Description
Rotate 	The Rotate cursor is activated by clicking in the upper-right corner. Rotate turns the image in a clockwise or counter-clockwise motion. The FOV center in the X and Y directions does not change. When in Step Mode, movement occurs in increments based on the value set in the Movement tools text box. This value is displayed in degrees.
Tilt 	The Tilt cursor is activated by clicking in the lower-left corner. Tilt rolls (obliques) the image in the direction of the arrow on the cursor. Movement occurs along the X-axis, the Y-axis or both. When in Step Mode, movement occurs based on the value set in the **deg** text box.
Translate 	The Translate cursor is activated by clicking in the lower-right corner. The image is rolled (obliqued) along the Z-axis, tilting toward or away from you with no change in the angle of the image. No movement occurs in the X or Y directions. When in Step Mode, movement occurs based on the value set in the **mm** text box. As movement begins, the arrow changes to display the direction of the translation.

The same Movement tools are available for both the Drive and Step modes. The mode simply determines the manner in which the scan plane changes are applied.

Drive Mode

The scan plane is navigated in Drive mode by clicking and dragging the mouse in the Main Viewer. The cursor indicates the direction of movement as the cursor is moved. As you drag the mouse, the extent of movement is annotated in the lower right corner of the real time image. The scan plane updates when you release the mouse button.

In Drive mode, the direction of mouse movement affects the direction of the cursor movement. The cursor icon changes to indicating the direction of movement.

NOTE: The Movement tool text boxes indicating the millimeter and degree of movement are not available in Drive mode. They can only be changed in Step mode.

Step Mode

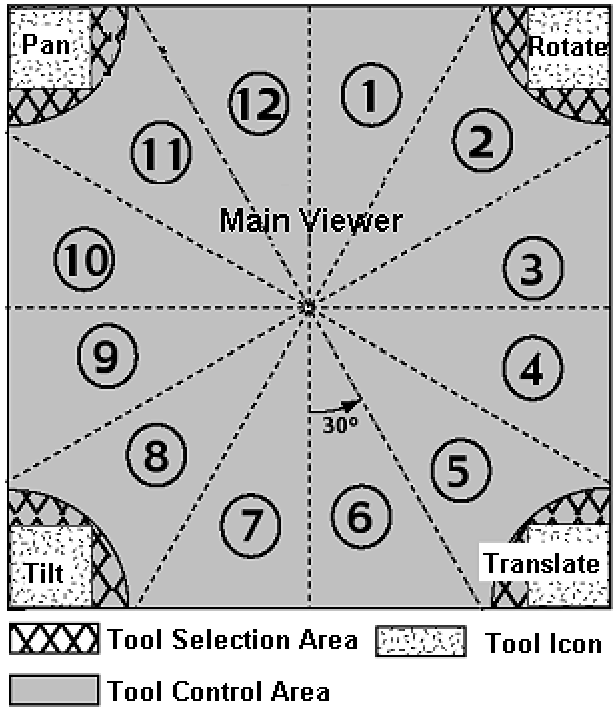
The scan plane is navigated by clicking the left mouse button. As the mouse button is released, the scan plane changes as determined by the increments set in the Movement tools millimeter and degree text boxes. The location of the cursor on the image determines the direction of movement when that tool is used at that point on the image.

When the Step mode is active, you can click and hold and an on-image counter displays. The display indicates the millimeter or degree of the scan plane change that takes place as long as the mouse button is held down. The counter display increases until the mouse button is released. When the mouse button is released, the value on the counter is the change applied to the real time image. The scan plane change depends on the active Movement tool when the mouse button was depressed.

In Step mode, the cursor indicates the direction of movement, but movement direction changes depending on the location of the cursor in the Main Viewer.

The Pan and Tilt tools divide the Main Viewer into 12 zones (Figure 18-7), numbered clockwise from 1 to 12. Each area corresponds to a different movement direction, depending on which tool is selected. Placing the cursor in the viewer and clicking shows location of the cursor at the time the mouse button was clicked. It also determines the movement for that zone and the cursor reflects the direction of that movement.

Figure 18-7 Control Zones and Location of Scan Controls



The Rotate tool divides the Main Viewer vertically into two zones. The cursor indicates the direction of movement. Clicking the cursor in the right half of the viewer results in clockwise movement. Clicking in the left half of the viewer results in counter-clockwise movement.

Translate divides the Main viewer horizontally into two zones. The cursor indicates the direction of movement. Clicking the cursor in the upper half of the viewer results in movement away from you. Clicking in the lower half of the viewer results in movement toward you.

NOTE: When in Step mode, using the right mouse button to initiate the on-image tools results in the opposite effect of using the left mouse button.

Orientation Tools

The orientation tools (Figure 18-8) quickly move the real time image to the specified orthogonal orientation.

Figure 18-8 Orientation Tools

For example, when the **[Axial]** button is clicked, the real time imaging plane moves to the axial plane at the current image center point. The **[Normal]** button moves the real time image to a normal viewing orientation at the current image center point. The image is presented such that RAS coordinates are in their "normal" positions in the viewer.

Contrast Tools

The Contrast tools (Figure 18-9) allow you to interactively make tissue contrast changes to the real time image. These tools apply tissue-specific techniques and are selected by either a push button or a toggle button. The Contrast tools available are based on the pulse sequence.

Figure 18-9 Contrast Tools

Table 18-3 lists the Contrast tools and provides a description of each.

Table 18-3 Contrast Tools

Contrast Tool	Description
[IR]	Available with FGRE. The IR single-shot inversion recovery pulse is applied once with the push button and an image is acquired with the IR pulse. The image then returns to its pre-IR pulse contrast.
[SAT]	Available with FGRE. Applies spatial saturation (SAT) slabs in the slice-select direction. The slabs are automatically concatenated and track the real time image plane. SAT is a toggle button and remains on until it is turned off.
[FatSAT]	Available with FGRE. Fat suppression can be used to null the signal from fat. FatSAT is a toggle button and remains on until it is turned off.
[SPGR]	Available with FGRE and Spiral sequences. A Gradient Echo sequence can be changed to a Spoiled Gradient Echo (RF spoiling) sequence. SPGR is a toggle button and remains on until it is turned off.
[FC]	Available with FGRE. Flow Compensation (FC) is used for gradient moment nulling to decrease flow artifacts. FC is a toggle button that remains on until it is turned off.
[SS]	Spectral Spatial (SS) is not currently available for any pulse sequence.

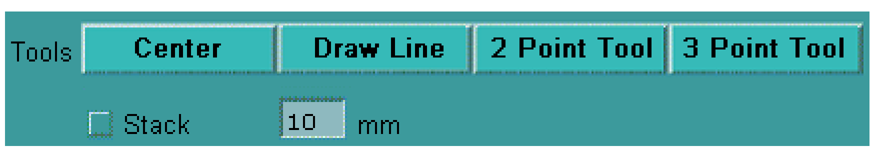
There are several factors you should consider when using the Contrast tools:

- In FGRE sequences with Real Time, FC and SAT selections (Fat Suppression and Spatial SAT) can be made from the SAT screen during series prescription. The corresponding button is depressed when the Acquire tab opens. These options can be turned on and off at the Acquire tab during real time data acquisition.
- SAT is applied in the slice select direction, and when SAT is turned on at the SAT screen, only SAT pulses in the slice-select direction are allowed.
- The Contrast tools are NOT available for FGRET Real Time (FGRET-RT) sequences. However, FC and Fat SAT can be selected during series prescription. They cannot be turned off at the Acquire tab.
- Only SPGR is available for Real Time Spiral sequences. Spectral Spatial RF (SSRF) or Fat SAT can be used with Real Time Spiral, but they must be selected during series prescription and they cannot be turned off or on at the Acquire tab.

Graphic Tools

The Graphic tools provide a means by which you can define a new real time image location by graphically prescribing cut planes through the imaging volume. The Graphic tools available are: Center, Draw Line, 2 Point Tool, and 3 Point Tool (Figure 18-10).

Figure 18-10 Graphic Tools



Center

Center changes the FOV center of the real time image to the location of a cursor placed on the real time image. This can be accomplished by selecting the **[Center]** button, placing the cursor on the new FOV center, and clicking the left mouse button to deposit the cursor. The real time image updates to reflect a FOV center at the point of the cursor. Once the new FOV center is defined, the Center tool turns off automatically.

Draw Line

Draw Line is used to define a new acquisition plane by drawing a line on the current real time image in the Main Viewer or on the scout image. Draw Line can also be used to define a stack in Multi-slice mode.

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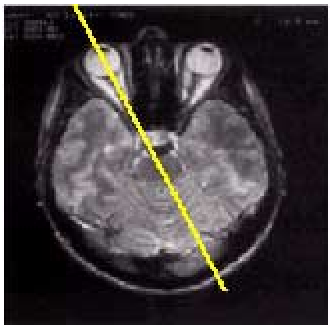
If no scout image has been defined, clicking the **[Draw Line]** button automatically deposits a line on the real time image in the Main Viewer. If a scout image has been defined, the cursor must be placed on either the scout or real time image, followed by a left click on the mouse. The line is deposited at the center of the image. Figure 18-11 illustrates a line defining the scan plane that runs along the optic nerve. The image plane becomes the plane defined by the line.

Figure 18-11 Draw Line Defining a Scan Plane

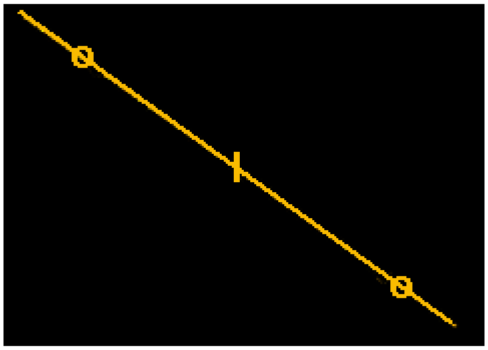


There are three applications for the Draw Line tool.

- Draw Line for the real time image Main Viewer
- Draw Line for the Scout Viewer
- Draw Line for Multi-slice Mode

Draw Line for the real time image Main Viewer draws a line onto the real time image to implement a change to the real time scan plane and acquires an image at the plane of that line. The line (Figure 18-12) deposited on the image is not an indicator of the selected FOV.

Figure 18-12 Real Time Image Main Viewer Line Tool



The line has three handles that are used to adjust the location and obliquity of the line.

- The middle handle (the crosshair) is used to drag the line in horizontal and vertical directions.

- Two circles, one towards each end of the line, are used to rotate the line.

Once the line has been adjusted, the **[GO]** button is selected in the Main Viewer to initiate the scan plane change. Alternately, right-click anywhere on the real time image in the Main or Scout Viewer to initiate the scan plane change.

Draw Line for the Scout Viewer is used to prescribe a real time scan plane orthogonal to the current scout image. With Draw Line selected, clicking the Scout Viewer displays a line. The real time scan plane moves to that location. The line (Figure 18-12) displays and operates the same as the line tool for the real time image Main Viewer.

The line handles are used to position the line segment at the desired location on the Scout Viewer. The real time Main Viewer tracks the position of the line and updates the real time image as the line is adjusted. Draw Line remains active until it has been toggled off, another graphic tool is clicked, or a click is performed on the real time image in the Main Viewer.

When the **Stack** box is checked, the Multi-slice mode is enabled. Multi-slice mode is used to visualize the extent of a multiple slice (stack) acquisition.

In the Multi-slice mode, Draw Line can be used on the Main Viewer real time image or in the Scout Viewer. When a line is dropped on an image, two additional line segments are displayed (smaller than the main line). The small line segment with the two notches at either end designates the first slice in the stack. The second small line segment indicates the last location in the stack. The **mm** text box to the right of the **Stack** check box determines the distance between the two small line segments in millimeters.

2 Point Tool

The 2 Point tool allows you to define an acquisition plane by depositing two points on the current real time image or on two different real time images. The on-image Movement tools are used to navigate the real time image to deposit a point on a second image. The plane resulting from the two points is positioned midway between the points, and perpendicular to the line defined by the points. Figure 18-13 illustrates the 2 Point tool defining the scan plane perpendicular to the optic nerve. The optic nerve will be viewed on end in the resulting image of this example.

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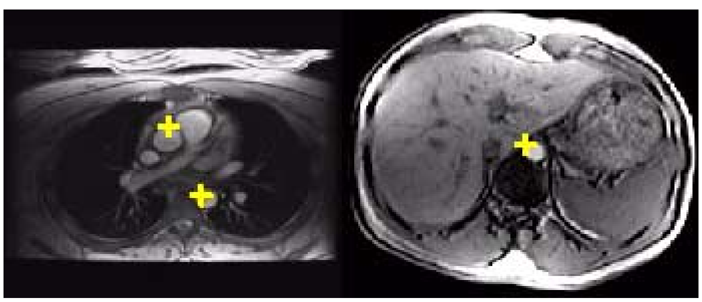
Figure 18-13 2 Point Tool Defining a Scan Plane

3 Point Tool

The 3 Point tool allows you to define an acquisition scan plane by depositing three points at selected locations on one, two, or three images. The on-image Movement tools are used to navigate the real time image to deposit a point on a second or third image. The plane resulting from these three points contains all three points. The 3 Point tool is typically used with complex anatomy that requires you to work with multiple images in a prescription. Figure 18-14 illustrates the 3 Point tool defining a scan plane along the thoracic aorta.

Figure 18-14 3 Point Tool Defining a Scan Plane

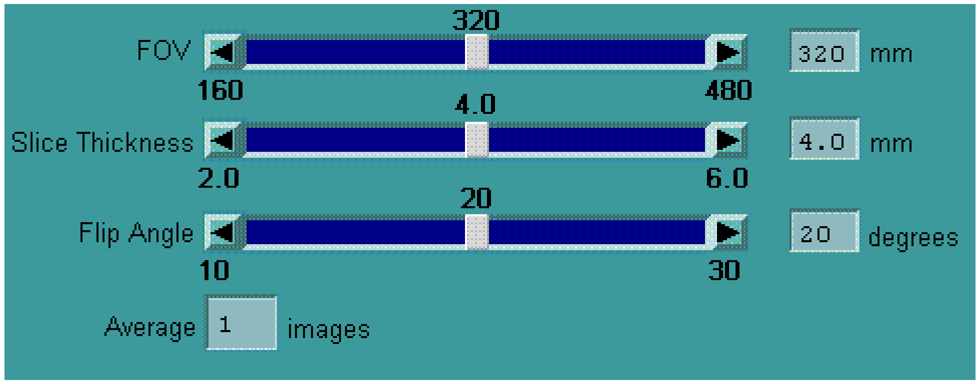


Parameter Tools

The FOV, slice thickness, flip angle, and number of averages can be changed interactively from the Acquire tab in *i*Drive Pro Plus for RTCAs. The RTCA Parameter tools (Figure 18-15) available depend on the selected pulse sequence.

Upon entering the Acquire tab, these parameters are set to the values prescribed at the Scan Rx desktop. The sliders can be used to make the change or a value can be entered in the text boxes.

Figure 18-15 RTCA Parameter Tools



Each parameter can be changed within the limits described in Table 18-4. If you enter a value that exceeds either the minimum or maximum allowed value, a default entry is made automatically. The default entry is either the minimum or maximum value, whichever is closer to the value you entered.

Table 18-4 RTCA Parameter Tool Limits

Parameter Tool	Limits
FOV	The FOV can be changed to a minimum of 50% and a maximum of 150% of the prescribed value. The change cannot exceed the minimum and maximum values based on the pulse sequence, series prescription, and system limitations. The slider and text box are based on millimeter changes (not centimeter) and when the slider is moved, changes occur in 10 mm increments. The FOV slider is not available for FGRET-RT.
Slice Thickness	The slice thickness can be changed to a minimum of 50% and a maximum of 150% of the prescribed value. The change cannot exceed the minimum and maximum values based on the pulse sequence, series prescription and system limitations.The slider changes the slice thickness in increments of 0.1 mm.
Flip Angle	The flip angle can be altered to 50% above and below the prescribed value. The flip angle cannot exceed the minimum and maximum values as determined by the pulse sequence. The slider changes the flip angle in increments of 1°.

Parameter Tool	Limits (Continued)
Average	The average value defines the number of reconstructed images that are averaged to create one real time image for each new scan plane. As averages increase, SNR increases and the frame rate may decrease due to a decrease in reconstruction time. Note that this is not the same as Number of Excitations (NEX). The allowable range for image averaging is one to eight. One means that image averaging will not be performed. The value steps in increments of one. Image averaging occurs as long as the interactive scan plane and contrast settings are not changed.

Graphic Prescription Tools

*i*Drive Graphic Prescription (IGRx) tools can be used to:

- Save start and end locations that can then be acquired at a later time in the real time session.
- Apply start and end locations that have been scanned and saved to the IGRx tools area during a real time session.
  - These locations can be applied to a series in the Rx Manager.
- Retrieve the start and end locations from a series (2D, 3D or Real Time) in the Rx Manager that can then be acquired at a later time in the real time session.
- Apply the center of a stack to a series in the Rx Manager.
  - The stack center is used by the series to determine the start and end locations based on the coordinates of the stack center and the slice thickness and spacing of the series.
- Retrieve the center location of a 3D series to be used in the current real time session.

NOTE: The series you wish to prescribe must be downloaded in the Rx Manager and highlighted prior to starting the RTCA.

Two methods of defining imaging locations can be performed, prescribing the start and end locations and prescribing the center location. It is not possible to retrieve slice locations from an Rx Manager series in which the slice locations have been graphically prescribed. Attempting to enter the Graphic Rx screen of a series in which a RTCA was used to apply locations results in the locations erasing.

Prescribing Start and End Locations

When the **[Rx Start/End]** button is clicked, the IGRx tools (Figure 18-16) allow image locations to be defined from a start and end perspective. The start and end locations displayed are the RAS coordinates of the center point of the image.

Figure 18-16 RTCA IGRx Tools

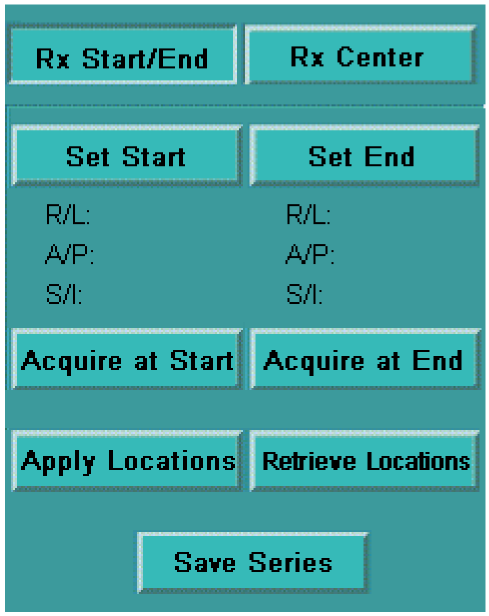


Table 18-5 lists the tools available in IGRx for RTCAs and a description of each.

Table 18-5 RTCA IGRx Tools and Descriptions

IGRx Tool	Description
[Rx Start/End]	Accesses the IGRx tools in the Rx Start/End mode.
[Rx Center]	Changes the IGRx tools area to the Rx Center mode.
[Set Start]	Saves the current position of the real time image as the first location of another series or to be used to acquire a real time image at that location. The saved start coordinates are displayed.
[Set End]	Saves the current position of the real time image as the last location of another series or to be used to acquire a real time image at that location. The saved end coordinates are displayed.

IGRx Tool	Description (Continued)
[Acquire at Start]	Prompts *i*Drive to scan an image at the locations defined by the **[Set Start]** button. This button is unavailable if a start location has not been defined.
[Acquire at End]	Prompts *i*Drive to scan an image at the locations defined by the **[Set End]** button. This button is unavailable if an end location has not been defined.
[Apply Locations]	Sends the current Start/End locations to the currently highlighted series in the Rx Manager. These locations become the prescribed slice locations for that series. Slice locations already prescribed are overwritten.
[Retrieve Locations]	Pulls the start and end slice locations from a series in the Rx Manager. The RAS coordinates of the start/end locations are displayed below the **[Set Start]** and **[Set End]** buttons in the IGRx tools area. These locations can then be used to obtain real time images at those locations. If the currently selected series has no prescribed start and end locations, the locations become (or remain) undefined.
[Save Series]	Saves the prescribed series in the Rx Manager. The series is then labeled as RXD in the Rx Manager.

When defining locations using the IGRx tools, consider the following:

- The start and end locations can be redefined by clicking the **[Set Start]** and **[Set End]** buttons. If the start and end locations have been defined and one of the buttons is clicked to redefine a location, the other location responds in one of the following fashions.
  - If the plane of the new location and the old location remain parallel, the old location remains as defined.
  - If the plane of the new location and the plane of the old location are consistent, the old location is deleted. A message posts to notify you of this action.
- Start and end locations can be the same location. This may be done when the locations are to be applied to a real time series in the Rx Manager.
- When using the **[Apply Locations]** button, the applied start and end locations may be rejected if the plane of the start and end locations do not match the plane of the series to which they are being applied. For example, locations can be applied oblique to oblique, axial to axial, etc. An error message posts if an incompatibility exists.
- If the number of slice locations being applied (when using Apply Locations) exceeds the maximum number of acquisitions for the

selected series in the RX Manager, an error message results stating, "Scn: Incompatible Scan Range. Apply Ignored."

- When using the **[Retrieve Locations]** button, if the Rx Manager series does not contain prescribed slices, the start and end coordinates remain clear.

Prescribing Center Locations

When the **[Rx Center]** button is selected during a RTCA, the IGRx tools allow image locations to be defined from a center of the stack perspective.

Figure 18-17 RTCA Center IGRx Tools

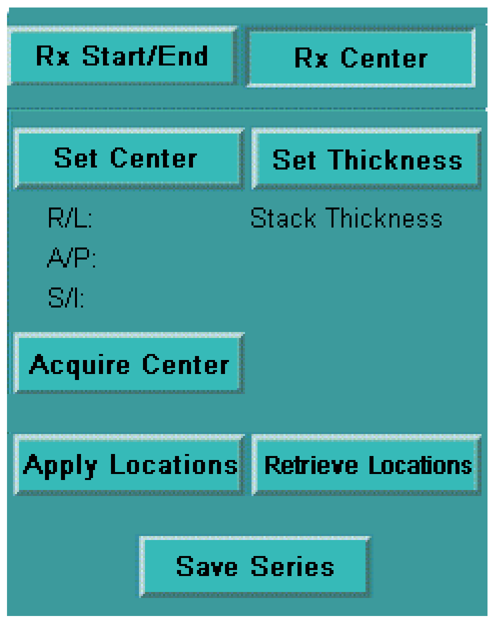


Table 18-6 lists the tools available in Center IGRx and a description of each.

Table 18-6 RTCA Center Tools and Descriptions

Center IGRx Tool	Description
[Rx Start/End]	Changes the IGRx tools area to the Rx Start/End mode.
[Rx Center]	Accesses the Rx Center IGRx tools.
[Set Center]	Saves the current position of the real time image for use as the center location for a series in the Rx Manager, or to be used to acquire a real time image at that location. The coordinates are displayed and the current stack value is entered as the Stack Thickness on the IGRx tools area.

Center IGRx Tool	Description (Continued)
[Set Thickness]	Allows you to change the stack thickness after the **[Set Center]** button has been clicked. Enter a new value in the **Stack** text box and click the **[Set Thickness]** button. The stack value currently in the **Stack** text box is entered as the Stack Thickness in the IGRx tools area.
[Acquire Center]	Obtains a real time image at the location displayed in the Rx Center tools area.
[Apply Locations]	Sends the stack locations to the currently highlighted series in the Rx Manager. These locations become the prescribed slice locations for that series. Slice locations already prescribed are overwritten.
[Retrieve Locations]	Pulls the slice locations from a series in the Rx Manager. The center slice of the series is used as the center of the stack and the thickness is based on the start/end locations of the series. The center location and thickness are displayed in the IGRx tools area and can be used to obtain real time images at those locations.
[Save Series]	Saves the prescribed series in the Rx Manager. The series is labeled “RXD” in the Rx Manager.

When defining locations using the Center IGRx tools in RTCAs, consider the following:

- By convention, when the center slice and stack thickness are used to define locations, the start location in that stack is the location nearest you in the real time viewer. The end location in the stack is the furthest away form you.
- It is possible for a stack to be applied to a series in the Rx Manager and a double acquisition results for that series. For example, the series slice thickness is 5 mm, spacing is 1 mm, and the maximum number of locations per acquisitions is 11. If the applied stack is 80 mm thick, a double acquisition is required to scan the entire stack. The series can only acquire 66 mm in a single acquisition.

Review Tab

The Review tab is used to view and save real time images residing in the Image Buffer. Viewing images can be done in a cine-style, movie mode, or a single image at a time. The defined image range determines the images available to be viewed.

Clicking the Review tab on the lower left corner of the Acquire tab accesses the Review tab. The Review tab takes longer to open as the Image Buffer becomes more full. If the Review tab is clicked while data acquisition is taking place, scanning pauses. When the Review tab (Figure 18-18) opens, the image displayed is the last image displayed in the Main Viewer on the Acquire tab.

Figure 18-18 RTCA Review Tab

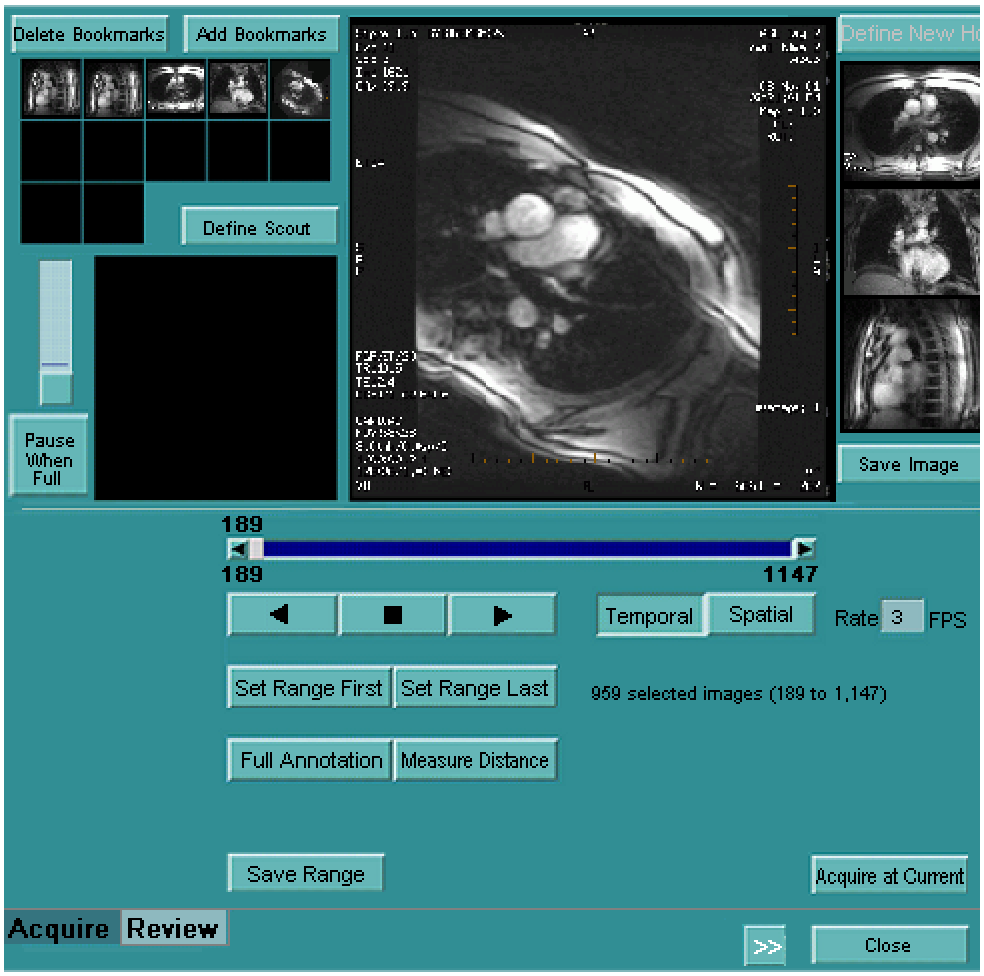
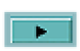
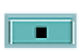
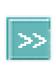


Table 18-7 provides a description and acceptable values for each selection on the Review tab in *i*Drive Pro Plus for RTCAs.

Table 18-7 RTCA Review Tab Selections and Descriptions

Selection	Description
[Delete Bookmarks]	Deletes all bookmark thumbnails currently displayed. Note that bookmarks created on the Acquire tab are shown on the Review tab. Individual bookmarks cannot be deleted.

Selection	Description (Continued)
[Add Bookmarks]	The plane, location, and image contrast of the image currently in the Review tab viewer is saved as a bookmark thumbnail for later recall. Bookmarks can be created and deleted in both the Acquire and Review tabs.
[Define Scout]	Copies the image in the Main Viewer to the Scout Viewer (the viewer directly under the **[Define Scout]** button). The new scout is also applied to the Scout Viewer on the Acquire tab.
[Define New Home]	Inactive on the Review tab.
[Pause When Full]	Automatically pauses the real time data acquisition when the real time image buffer is full. The progress bar provides a graphic display of the image buffer capacity.
[Save Image]	Saves the image in the Review tab Main Viewer to the system disk. When a saved image is displayed, the word “Saved” is seen below this button.
Image Slider	Allows you to move through the images to change the image currently displayed in the viewer.
Play Back Button: Play Forward 	Starts a movie in a forward play motion. The images are displayed in movie playback in ascending image number order, starting at the first image in the defined range. The Image Slider updates to reflect the image that is currently being viewed.
Play Back Button: Stop Play 	Stops the movie playback. You can also stop playback by pressing the selected toggle that started play.
Play Back Button: Play Backward 	Starts a movie in a backward play motion. The images are displayed in movie playback in descending image number order, starting at the last image number defined in the image range. Play continues according to the temporal or spatial play mode selected.
[Temporal]	Plays the movie images in a continuous loop from first to last. When the end of the range is reached, play wraps to the first image again. For example, an image set consisting of four images appears in the following order: 1, 2, 3, 4, 1, 2, 3, 4, etc.

Selection	Description (Continued)
[Spatial]	Plays the movie images forward, then backward in a repeating loop. Image play effectively "bounces" off the end of the range in a forward and backward direction. For example, an image consisting of four images appears in the following order:1, 2, 3, 4, 3, 2, 1, etc.
FPS	Frames per Second (FPS) defines the rate of movie playback. The valid range is 1 to 60 FPS. If you enter a value higher than the system allows, the maximum allowed value of 60 is displayed.
[Set Range First]	Defines the first image to be included in a range for saving, or set of images for displaying in movie mode.
[Set Range Last]	Defines the last image to be included in a range for saving, or set of images for displaying in movie mode.
[Full Annotation]	Displays all image annotation in the main viewer. Otherwise, only partial annotation is displayed.
[Measure Distance]	Displays a line on the main image. The length and angle of the line can be adjusted by dragging either end. You can change the line location by clicking and dragging anywhere, other than the ends of the line. The line length and angle from vertical is displayed on the image.
[Save Range]	Saves the range of images defined on the Review tab to the system disk. As the images are being saved, a status box displays, counting down the number of images yet to be saved. You can cancel the save during the save operation. When a saved image is displayed in the Main Viewer, the word "Saved" is seen below the **[Save Image]** button.
[Acquire at Current]	Returns the display to the *i*Drive Acquire tab and begins data acquisition at the image location currently displayed in the Review tab Main Viewer.
[Acquire]	Returns the display to the *i*Drive Acquire tab.
Message Area 	Displays messages at the bottom of the Review tab. Click the button to display a list of messages for the current real time session.
[Close]	Exits the Review tab, stops the current real time session, and returns to the Scan Rx desktop.

Review Images

Real time images are not automatically saved to the system disk. The **[Save Image]** button is used to save a single 128x128 image to the disk when that image is displayed in the Acquire tab Main Viewer, or via the **[Save Image]** or **[Save Range]** buttons on the Review tab. When a saved image is displayed in the Review tab, the word "Saved" is seen below the **[Save Image]** button. This is not true when displaying images in the Acquire tab.

Bookmarks in the Review tab cannot be used to initiate data acquisition as can be done in the Acquire tab.

Annotation on the real time image indicates the parameters with which that image was acquired, including those parameters changed at the Acquire tab. Partial annotation (Table 18-8) is displayed, unless you click the **[Full Annotation]** button.

Table 18-8 Partial Annotation Selections

Partial Annotation Selections
System
Hospital
Time
Magnification, Filtering, and Rotation Factors
PSD
Sequence Parameters
Slice Thickness and Spacing

Image Slider

Images currently in the real time Image Buffer can be displayed using the Image Slider (Figure 18-19). The Image Slider is set to the number of the last real time image acquired before pausing. The image displayed on the viewer is the same image. The Image Slider can define or redefine the image range that is used for saving or playing real time images.

Figure 18-19 Image Slider

There are four ways to move through the images in the Review tab and select an image number for display.

- Dragging the slider.
  - As the slider moves, the image in the viewer updates to the image on the slider.
- Clicking the arrows at either end of the slider.
- Clicking the slider background.
  - This displays the image associated with that point on the slider.
- Pressing the **Page Up** and **Page Down** hard keys on the keyboard.

Within Review, the operations of playing and saving images are applied to a single defined range of images within the image buffer. The number of the image currently shown in the viewer is labeled above the slider, as well as, on the image. At both ends of the slider the range of images is also displayed. Upon entering the Review tab, the range of images indicates all the images in the buffer. The image numbers shown indicate how many images have been acquired during the real time session; therefore, they may be numbered in the hundreds or thousands.

The background of the slider is shaded to indicate the range of images defined by the Set Range buttons. Initially, the background is completely shaded. If the range of images is changed, only the area of the slider associated with the image range is shaded. If an attempt is made to set the first image in the range to a value greater than the currently defined last image in the range, the first and last images are swapped.

Applications

The RTCA application consists of a continuous high-temporal-resolution acquisition, reconstruction, and display of low spatial resolution images. This allows you to instantaneously view anatomy and interactively make contrast adjustments and prescribe scan planes. Real time imaging works well to monitor temporal physiological events.

Use real time imaging to:

- Navigate through patient anatomy for orientation to “scope out the lay of the land.”
- Rapidly localize anatomical landmarks of interest.
- Define the boundaries of an imaging volume.
- Localize complex anatomy or anatomical anomalies that lie in double oblique planes.
- Monitor temporal events such as the passage of a contrast timing bolus.
- Image dynamic joint studies.
- Know what the scan looks like before investing the scan time.

Troubleshooting Tips

The following section gives you tips for troubleshooting errors when scanning RTCAs with *i*Drive Pro Plus.

If you click the **[Scan]** button too quickly following pressing the **Stop Scan** hard key and closing the RTCA interface, *i*Drive is not prepared to begin data acquisition. An error message posts, “Prep action failed, please try again.”

For example, the following scenario may result in the failure to start a real time data acquisition.

1. A real time acquisition is paused by selecting the **[Pause Scan]** button at the Acquire tab.
2. The **Stop Scan** hard key on the keyboard is pressed.
3. The **[Close]** button is selected at the Acquire tab and the real time interface closes.
4. The **[Scan]** button is clicked at the Scan Rx desktop quickly after the real time interface closes.

At this time, the real time data acquisition should be initiated. Instead, the error message posts because *i*Drive is not ready to begin the data acquisition.

Error messages posted in the message log also include:

- Proc: scn Error: XXXXXXXXXX
- Unexpected allocDone packet received from IFCC for sequence number XX. Proc: NSP Error: XXXXXXXXXX
- An unexpected CERD Network packet was received by ASC Data Acquisition during acquisition.
- Internal software error, please retry the acquisition!

Should it be necessary for you to stop a scan and close *i*Drive as stated in the steps above, it is recommended the real time series be copied and pasted and the data acquisition be started from the new series. Alternatively, wait a period of time before selecting the **[Scan]** button and re-starting the real time acquisition. The exact amount of time needed for *i*Drive to be ready is not known. It is recommended that you wait at least five seconds before restarting the acquisition.

How Do I...

This section provides the step-by-step instructions for imaging real time with *i*Drive Pro Plus. Specifically, it describes how to:

- Prescribe a real time sequence
- Use the Movement tools
  - Drive through an image volume
  - Step through an image volume
- Manage Home Images
  - Define a scan plane
  - Define new Home Images
- Manage Bookmarks
  - Create a Bookmark
  - Recall a Bookmark
  - Enlarge a thumbnail to apply for scanning
- Use the Graphic tools
  - Change the FOV center
  - Draw a line in the Main Viewer
  - Draw a line in the Scout Viewer
  - Draw a line in the Multi-slice Mode
  - Apply the 2 Point tool
  - Apply the 3 Point tool
- Review real time images
  - Playback images
  - Save images

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Prescribe a Real Time Sequence

The Real Time Imaging Option can be used for RTCAs to navigate through your patient's anatomy for rapid visualization and monitoring of temporal physiological events. Real time images can also be used for directly prescribing scan planes of other series in the exam.

Use this procedure to prescribe a real time sequence. The PSD you select determines which values in each area need entered. You need to enter a value in all active fields.

1. Click **[New Series]**.
   - Located in the Rx Manager.
2. Enter the Patient Position parameters.
   - Patient Position
   - Patient Entry
   - Coil
     - Real Time is compatible with all coils. The use of a phased array coil may decrease the frame rate as compared to a single receive coil.
   - Series Description
3. Enter the Imaging Parameters.
   - Plane
     - Real Time can be initiated in any orthogonal plane. Oblique planes may be prescribed using an explicit coordinate entry or from localizer images using Graphic Rx tools.
   - Mode
     - 2D is the only valid mode with Real Time.
   - Gradient Mode
     - Real Time is compatible with any gradient mode.
   - Pulse Sequence
     - PSDs available with *i*Drive Pro Plus: Fast GRE, Fast SPGR, Fast GRE ET, Spiral GRE, and Spiral SPGR

Quick Steps: Prescribe a Real Time Sequence

1. Click **[New Series]**.
2. Enter the Patient Position parameters.
3. Enter the Imaging Parameters.
4. Enter the Scan Timing parameters.
5. Enter the Scanning Range parameters.
6. Enter the Acquisition Timing parameters.
7. Click **[Save Series]**.
8. Click **[Prepare to Scan]**.
9. Click **[Scan]**.

- Imaging Options
  - Real Time must be selected to enter the feature.
  - Other compatible options are Flow Compensation and No Phase Wrap.

4. Enter the Scan Timing parameters.
   - TE
   - TR
   - Flip Angle
   - Echo Train Length
   - Bandwidth
5. Enter the Scanning Range parameters.
   - FOV
   - Slice Thickness
     - This value can be changed during *i*Drive Pro Plus data acquisitions.
   - Start and End Locations
     - Only one slice location is allowed for real time sequences.
6. Enter the Acquisition Timing parameters.
   - Frequency Matrix or Points
   - Phase Matrix or Arms
   - Phase FOV
   - Freq DIR
   - Auto Center Frequency
7. Click **[Save Series]**.
   - Closes the scan prescription screen, accepts the prescription, and saves it in the Rx Manager as RXD.
8. Click **[Prepare to Scan]**.
   - Downloads the series.
9. Click **[Scan]**.
   - Initiates Auto Prescan and the Acquire tab opens.
   - Home Images are acquired.

Use the Movement Tools

Drive Through an Image Volume

The scan plane of your RTCA can be manipulated and you can navigate through an image volume using the Movement tools. Each Movement tool is activated by an on-image icon on the real time Main Viewer. RTCAs begin in the Drive mode with the Translate tool active.

1. Move the mouse over the real time image in the Main Viewer until the cursor changes shape.
2. Click in Tool Selection area of desired tool.
   - Cursor icon indicates the function of the tool.
3. Click and drag on the real time image in the Main Viewer.
   - Your cursor indicates the direction of movement by displaying the icon associated with that tool accessed in that corner and the image moves in the direction of the cursor.
   - The extent of movement is annotated in the lower-right corner of the real time image.

   a) Move the cursor to the upper-left corner.
      – Activates the Pan tool to scroll the image in the X and Y directions.

   b) Move the cursor to the upper-right corner.
      – Activates the Rotate tool to turn the image in a clockwise or counter-clockwise motion.

   c) Move the cursor in the lower-left corner.
      – Activates the Tilt tool to roll the image in the direction of the arrow on the cursor.

   d) Move the cursor in the lower-right corner.
      – Activates the Translate tool to oblique the image along the Z axis, tilting the image away from you.
4. Release the mouse button.
   - The scan plane of the real time image updates.

NOTE: Click **[Undo]** to cancel the location changes all the way back to the start of motion, at the last mouse click.

Quick Steps: Drive Through an Image Volume

1. Move the mouse over the real time image in the Main Viewer until the cursor changes shape.
2. Click in Tool Selection area of desired tool.
3. Click and drag on the real time image in the Main Viewer.
4. Release the mouse button.

Quick Steps: Step Through an Image Volume

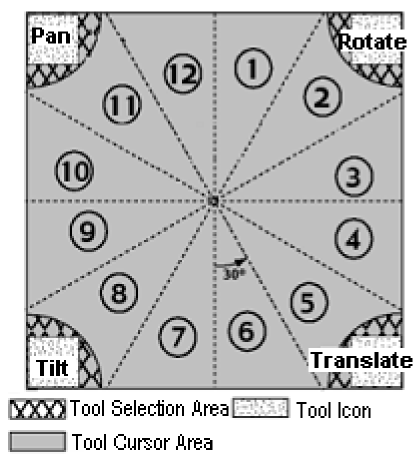
1. Click **[Step]**.
2. Click in Tool Selection area of desired tool.
3. Click and hold on the real time image in the Main Viewer.
4. Release the mouse button.

Use the Movement Tools

Step Through an Image Volume

The scan plane can also be manipulated using the Movement tools accessed in the Step mode for RTCAs. In the Step mode, the cursor indicates the direction of movement, but movement direction changes depending on the location of the cursor in the Main Viewer.

1. Click **[Step]**.
   - Your cursor location determines the direction of movement.
   - Movement direction changes when a specific tool is used at that point on the image.
2. Click in Tool Selection area of desired tool.
   - Cursor indicates direction of motion that will be induced.



Control Zones and Location of Scan Controls

3. Click and hold on the real time image in the Main Viewer.
   - An on-image counter displays, indicating the millimeters or degrees of the scan plane change that takes place as long as the mouse button is held down.

   a) Click one of the twelve zones on the image in the Main Viewer.
      – Activates the Pan and Tilt tools to move the image in the X and Y directions based on the value in the **mm** or the **degrees** text box, respectively.

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b) Click in the right-half of the Main Viewer to move clockwise or in the left-half to move counter-clockwise.

   – Activates the Rotate tool to turn the image based on the value set in the **degrees** text box.

c) Click in the upper-half of the Main Viewer to move the image away from you or in the lower-half to move the image towards you.

   – Activates the Translate tool to oblique the image along the Z axis, moving the image away or towards you based on the value set in the **mm** text box.

4. Release the mouse button.

   - Applies the value on the counter to move the scan plane of the real time image that amount.
   - The scan plane of the real time image updates.

NOTE: Click **[Undo]** to cancel the location changes all the way back to last mouse click.

Quick Steps: Define a Scan Plane

1. Prescribe a real time sequence.
2. Click **[Scan]**.
3. Click one of the Home Images.

Manage Home Images

Define a Scan Plane

Home Images are the three orthogonal images acquired upon initialization of a real time series that are displayed in the vertical viewers along the right side of the Acquire tab Main Viewer. The Home Images are created axially, sagittally, and coronally, based on the locations prescribed at the Scan Rx desktop during the real time series prescription. These images can be used to define an orthogonal scan plane and reset your current scan plane.

Use this procedure to define a scan plane based on the Home Images.

1. Prescribe a real time sequence.
2. Click **[Scan]**.
    - Acquire tab opens.
    - Home Images are acquired.
3. Click one of the Home Images.
    - The system obtains a real time image in the scan plane of the selected Home Image.

Manage Home Images

Define New Home Images

Home Images are the three orthogonal images acquired upon initialization of a real time series that are displayed in the vertical viewers along the right side of the Acquire tab Main Viewer. The Home Images are created axially, sagittally, and coronally, based on the locations prescribed at the Scan Rx desktop during the real time series prescription. You have the ability to define new Home Images.

Use this procedure to replace your Home Images with new images at the desired at the location of the current real time image.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement tools, if necessary.
2. Click **[Define New Home]**.
   - Located at the top-right corner of the Acquire tab.
   - The system informs you that if you define new Home Images, your current home locations will be replaced.
3. Click **[OK]**.
   - The system acquires and displays three new Home Images.
     - The images are perpendicular to the location of the real time image in the Main Viewer.
     - The images include the RAS offsets of the real time image in the Main Viewer.

Quick Steps: Define New Home Images

1. Display the desired real time image in the Main Viewer.
2. Click **[Define New Home]**.
3. Click **[OK]**.

Quick Steps: Create a Bookmark

1. Display the desired real time image in the Main Viewer.
2. Click **[Add Bookmark]**.

Manage Bookmarks

Create a Bookmark

Real time images can be bookmarked to recall at a later time. A bookmarked thumbnail obtains the scan plane and image contrast from that image and stores it in the Bookmark Viewers.

Use this procedure to create a Bookmark.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement Tools, if necessary.
2. Click **[Add Bookmark]**.
   - Creates a bookmark thumbnail of the current image in the Main Viewer.

NOTE: If all Thumbnail Viewers are filled, a message posts, telling you to right-click an occupied Bookmark to replace the thumbnail image with the current image in the Main Viewer.

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Manage Bookmarks

Recall a Bookmark

A recall can be performed on a bookmark to obtain the scan plane and image contrast from that image. The bookmarks are held in the Acquire tab when the current real time session is closed and upon re-entry into the RTCA, those bookmark thumbnails are displayed as long as the Patient ID, Landmark, and Patient Position have not changed.

Use this procedure to recall a Bookmark.

1. Click **[Scan]**.
   - Acquire tab opens.
2. Click the desired bookmark thumbnail image.
   - The system scans the new image based on the scan plane and image contrast of the thumbnail image.

Quick Steps: Recall a Bookmark
1. Click **[Scan]**. 2. Click the desired bookmark thumbnail image.

Quick Steps: Enlarge a Thumbnail to Apply for Scan

1. Place cursor over desired thumbnail image.
2. Click the enlarged image.

Manage Bookmarks

Enlarge a Thumbnail to Apply for Scan

A single bookmark thumbnail image acquired during a RTCA with *i*Drive Pro Plus can be enlarged from a 64x64 to 128x128 pixel display. This enlarged thumbnail can be applied for scanning in the real time Main Viewer.

Use this procedure, while the Acquire tab is opened, to enlarge a bookmark thumbnail to apply for scanning.

1. Place cursor over desired thumbnail image.
   - Leave cursor over thumbnail for at least one second.
     - The image enlarges.
   - The thumbnail image returns to its original size when the cursor is moved off the Thumbnail Viewer.
2. Click the enlarged image.
   - The system begins scanning the image.

Use the Graphic Tools

Change the FOV Center

The Graphic tools provide a means by which you can define a new real time image location. The Center tool in *i*Drive Pro Plus changes the FOV center of the real time image of a RTCA to a new location. This Graphic tool is located in the Tool area of the Acquire tab.

Use this procedure to change the FOV center of the real time image to the location of a cursor placed on the real time image.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement tools, if necessary.
2. Click **[Center]**.
3. Place the cursor at the desired FOV center.
   - This point will be the center of your new image location.
4. Click the real time image.
   - Updates real time image to reflect the new FOV center at the point of the cursor.

NOTE: The Center tool turns off automatically.

Quick Steps: Change the FOV Center

1. Display the desired real time image in the Main Viewer.
2. Click **[Center]**.
3. Place the cursor at the desired FOV center.
4. Click the real time image.

Use the Graphic Tools

Draw a Line in the Main Viewer

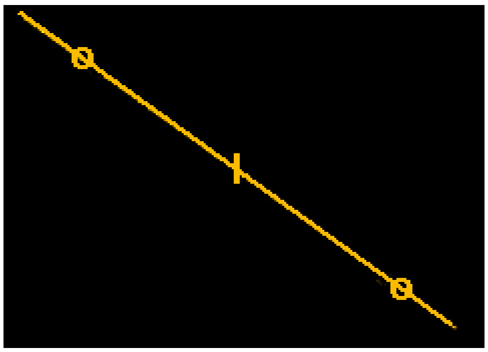
Quick Steps: Draw a Line in the Main Viewer

1. Display the desired real time image in the Main Viewer.
2. Click **[Draw Line]**.
3. Move the line to the desired position.
4. Rotate the line to the desired position.
5. Click **[GO]**.

The Draw Line tool allows you to draw a line on the current real time image in the Main Viewer to acquire an image at the plane of the line. This Graphic tool is located in the Tool area of the Acquire tab.

Use this procedure to draw a line on the real time image in the Main Viewer to define a new scan plane.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement tools, if necessary.
2. Click **[Draw Line]**.
   - A line appears on the image in the Main Viewer.
     – If a line does not appear, click on the real time image.



Draw Line Tool

3. Move the line to the desired position.
   - Click and drag the middle handle of the line.
     – Moves the line in the horizontal and vertical directions.
4. Rotate the line to the desired position.
   - Click and drag one of the circle handles of the line.
     – Rotates the line clockwise or counter-clockwise.
5. Click **[GO]**.
   - Alternatively, you may right-click anywhere on the real time image.
   - An image is acquired at the plane defined by the line.

NOTE: Draw Line remains active until you toggle it off, click another Graphic tool, or a click on the Scout image.

Use the Graphic Tools

Draw a Line in the Scout Viewer

The Draw Line tool for the Scout Viewer in *i*Drive Pro Plus allows you to prescribe a new acquisition plane orthogonal to the current Scout image. This Graphic tool is located in the Tool area of the Acquire tab.

Use this procedure to draw a line on the real time image in the Scout Viewer.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement tools, if necessary.
2. Click **[Define Scout]**.
   - Copies the image in the Main Viewer to the Scout Viewer.
3. Click **[Draw Line]**.
4. Click the image in the Scout Viewer.
   - A line appears on the image in the Scout Viewer.
   - The real time image scan plane moves to that location.
5. Move the line to the desired position.
   - Click and drag the middle handle of the line.
     – Moves the line in the horizontal and vertical directions.
     – Updates the real time image to reflect changes.
6. Rotate the line to the desired position.
   - Click and drag one of the circle handles of the line.
     – Rotates the line clockwise or counter-clockwise.
     – Updates the real time image to reflect changes.

NOTE: Draw Line remains active until you toggle it off, click another Graphic tool, or a click on the real time image in the Main Viewer.

Quick Steps: Draw a Line in the Scout Viewer

1. Display the desired real time image in the Main Viewer.
2. Click **[Define Scout]**.
3. Click **[Draw Line]**.
4. Click the image in the Scout Viewer.
5. Move the line to the desired position.
6. Rotate the line to the desired position.

Quick Steps: Draw a Line in the Multi-Slice Mode

1. Display the desired real time image in the Main Viewer.
2. Select **Stack**.
3. Click **[Draw Line]**.
4. Click the image in the Main or Scout Viewer.
5. Enter a value in the **mm** text box.

Use the Graphic Tools

Draw a Line in the Multi-slice Mode

Multi-slice mode is used to visualize the extent of a multiple slice (stack) RTCA in *i*Drive Pro Plus. Drawing a line in the Multi-slice mode can be performed in the Main Viewer or in the Scout Viewer. This Graphic tool is located in the Tool area of the Acquire tab and the Stack option is located below the tools.

Use this procedure to draw a line in the Multi-slice mode to visualize the distance of a multi-slice acquisition.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement tools, if necessary.
2. Select **Stack**.
   - Enables Multi-slice mode.
3. Click **[Draw Line]**.
4. Click the image in the Main or Scout Viewer.
   - A line appears on the real time image.
   - Two smaller line segments display (smaller than the main line).
     - The small line segment with two notches at either end indicates the first slice in the stack.
     - The second small line segment indicates the last location of the stack.
5. Enter a value in the **mm** text box.
   - Acceptable values are 10 to 100.
   - This value determines the distance between the two small line segments.

Use the Graphic Tools

Apply the 2 Point Tool

The 2 Point Tool allows you to define an acquisition plane by depositing two points on the current real time image or on two different real time images. The plane resulting from the two points is positioned midway between the points and orthogonal to the line defined by the points. This Graphic tool is located in the Tool area of the Acquire tab.

Use this procedure to define an acquisition plane perpendicular to a line deposited by two points.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement tools, if necessary.
2. Click **[2 Point Tool]**.
   - Two toggle buttons appear.
     – Point 1 (toggled on)
     – Point 2
3. Place the cursor at the point you wish to deposit Point 1 on the real time image.
4. Click the real time image.
   - Deposits Point 1.
   - Toggles the **[Point 1]** button off.
     – Clicking **[Point 1]** again allows the point to be repositioned.
5. Navigate to the desired image plane for Point 2.
   - Use the Movement tools, if necessary.
6. Click **[Point 2]**.
7. Place the cursor at the point you wish to deposit Point 2 on the real time image.
8. Click the real time image.
   - Deposits Point 2.
   - Acquires an image perpendicular to the line connecting the two points and displays the new image.

NOTE: The 2 Point Tool turns off automatically.

Quick Steps: Apply the 2 Point Tool

1. Display the desired real time image in the Main Viewer.
2. Click **[2 Point Tool]**.
3. Place the cursor at the point you wish to deposit Point 1 on the real time image.
4. Click the real time image.
5. Navigate to the desired image plane for Point 2.
6. Click **[Point 2]**.
7. Place the cursor at the point you wish to deposit Point 2 on the real time image.
8. Click the real time image.

Quick Steps: Apply the 3 Point Tool

1. Display the desired real time image in the Main Viewer.
2. Click **[3 Point Tool]**.
3. Place the cursor at the point you wish to deposit Point 1 on the real time image.
4. Click the real time image.
5. Navigate to the desired image plane for Point 2.
6. Click **[Point 2]**.
7. Place the cursor at the point you wish to deposit Point 2 on the real time image.
8. Click the real time image.
9. Navigate to the desired image plane for Point 3.
10. Click **[Point 3]**.
11. Place the cursor at the point you wish to deposit Point 3 on the real time image.
12. Click the real time image.

Use the Graphic Tools

Apply the 3 Point Tool

The 3 Point Tool allows you to define an acquisition scan plane by depositing three points at selected locations on one, two, or three images. The image plane resulting from these three points contains all three points. This Graphic tool is located in the Tool area of the Acquire tab.

Use this procedure to define a cut plane when you need to use more than one image location and you want an image plane along the plane defined by the points.

1. Display the desired real time image in the Main Viewer.
   - Use the Movement tools, if necessary.
2. Click **[3 Point Tool]**.
   - Three toggle buttons appear.
     - Point 1 (toggled on)
     - Point 2
     - Point 3
3. Place the cursor at the point you wish to deposit Point 1 on the real time image.
4. Click the real time image.
   - Deposits Point 1.
   - Toggles the **[Point 1]** button off.
     - Clicking **[Point 1]** again allows the point to be repositioned.
5. Navigate to the desired image plane for Point 2.
   - Use the Movement tools, if necessary.
6. Click **[Point 2]**.
7. Place the cursor at the point you wish to deposit Point 2 on the real time image.
8. Click the real time image.
   - Deposits Point 2.
   - Toggles the **[Point 2]** button off.
     - Clicking **[Point 2]** again allows the point to be repositioned.

9. Navigate to the desired image plane for Point 3.
   - Use the Movement tools, if necessary.
10. Click **[Point 3]**.
11. Place the cursor at the point you wish to deposit Point 3 on the real time image.
12. Click the real time image.
    - Deposits Point 3.
    - Acquires and displays the new image.

NOTE: The 3 Point Tool turns off automatically.

Review Real Time Images

Playback Images

Quick Steps: Playback Images

1. Click **[Review]**.
2. Define the range of images for movie playback.
3. Select the movie mode.
4. Enter a value in the **FPS** text box.
5. Click the **Play Forward** or the **Play Backward** icon.
6. Click the **Stop** icon.

Real time images residing in the Image Buffer can be viewed in the Review tab. Images can be viewed cine-style, in a movie mode, or by a single image at a time. The Review tab is accessed on the lower left corner of the Acquire tab and can be opened while scanning is taking place.

Use this procedure to playback images in the Image Buffer.

1. Click **[Review]**.
   - Pauses scanning.
   - Opens the Review tab.
2. Define the range of images for movie playback.
   - All images in the buffer can be viewed. If this is desired, continue with step 3.

   a) Click and drag the Image Slider to the first image.

   b) Click **[Set Range First]**.

   c) Click and drag the Image Slider to the last image.

   d) Click **[Set Range Last]**.
3. Select the movie mode.
   - Click **[Temporal]**.
     – Plays images in a continuous loop.
   - Click **[Spatial]**.
     – Plays images forward, then backward.
4. Enter a value in the **FPS** text box.
   - Defines the rate of movie playback.
   - Valid entries are 1 to 60.
5. Click the **Play Forward** or the **Play Backward** icon.
   - Starts movie playback in ascending or descending order, respectively.
6. Click the **Stop** icon.
   - Stops movie playback.
   - At this point, another range of images can be defined.

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Review Real Time Images

Save Images

Real time images are not automatically saved to the system disk. Real time images residing in the Image Buffer can be saved in the Review tab. An image group or a single image can be saved at one time. The Review tab is accessed on the lower left corner of the Acquire tab and can be opened while scanning is taking place.

Use this procedure to save images in the Image Buffer.

1. Click **[Review]**.
   - Pauses scanning.
   - Opens the Review tab.
2. Define the range of images for saving.
   - All images in the buffer can be saved. If this is desired, continue with step 3.

   a) Click and drag the Image Slider to the first image.

   b) Click **[Set Range First]**.

   c) Click and drag the Image Slider to the last image.

   d) Click **[Set Range Last]**.
3. Click **[Save Range]**.
   - A confirmation message appears showing the number of images to be saved.
   - Saves images to the Browser list.
   - Alternatively, images can be saved one at a time.
     – Display images in the viewer.
     – Click **[Save Image]**.

Quick Steps: Save Images

1. Click **[Review]**.
2. Define the range of images for saving.
3. Click **[Save Range]**.

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Chapter 19

Spectroscopy FuncTool 2

Introduction

FuncTool 2 is a post processing tool used to display advanced level Magnetic Resonance Imaging (MRI) and Magnetic Resonance Spectroscopy (MRS) images. Specially designed algorithms programmed into FuncTool 2 protocols can be used to portray various pixel intensity settings.

This chapter describes example Spectroscopy post processing techniques. You must first acquire a Spectroscopy sequence in order to perform any of these post processing procedures. This chapter contains the step-by-step instructions to help you learn how to:

- Display Images and Spectrums
- Display Regions of Interest

In addition, this chapter answers the following questions:

1. What are the prostate algorithms?
2. What are the brain algorithms?
3. What type of image sets can be processed with FuncTool 2?

What Do I Need to Know About...

This section presents the concepts necessary to successfully complete the FuncTool 2 post processing techniques with Spectroscopy image data. Specifically, you need to understand:

- FuncTool 2 Basics
- Valid Image Sets
- Predefined Algorithms

FuncTool 2 Basics

FuncTool 2 is an optional image analysis software package, that processes dynamic image data to generate information with regard to changes in image intensity over time in the form of graphs and parametric images.

Valid Image Sets

An MRS data set is an ordered acquisition with sequential changes in frequency. The horizontal scale of a graph for such a data set represent parts per million (ppm) values. PROstate Spectroscopy and imaging Examination (PROSE) and Single-voxel Proton Brain Examination (PROBE) sequences qualify as valid image data sets.

Predefined Algorithms

FuncTool 2 has predefined algorithms for your use to calculate the metabolite or metabolite ratio maps. Table 19-1 lists the protocols for the brain and prostate.

Table 19-1 Predefined Brain and Prostate Algorithms

Brain	Prostate
N-Acetyl	Choline
Choline	Creatine
Composite	Creatine + Choline
Startup	Choline/Creatine
Creatine	Lipid and Lactate
Lactate Lipid	Citrate

Brain	Prostate
Choline/Creatine	Choline + Creatine/Citrate
Choline/N-Acetyl	Composite Image
	Signal Over Noise Ratio

A brief description of the predefined protocols are listed in Table 19-2.

Table 19-2 Protocols And Descriptions

Protocols	Descriptions
Choline	Displays the averaged, absolute pixel values from CSI images 64 to 74 as a metabolite map.
Creatine	Displays the averaged, absolute pixel values from CSI images 78 to 88, as a metabolite map.
Creatine + Choline	Displays the sum of pixel values from PROSE images 66 to 85, as a metabolite map.
Choline/Creatine	Displays a map of the ratio of the choline, 64 to 74 region, to the creatine, 78 to 88 region.
Lipid and Lactate	Displays the sum of pixel values from images 183 to 222, as a metabolite map.
Citrate	Displays the averaged, absolute pixel values from PROSE images 95 to 114, as a metabolite map.
Choline + Creatine/Citrate	Displays a map of the ratio of the choline + creatine, images 66-85 compared to citrate, images 95-114.
N-Acetly	Displays the averaged, absolute pixel values from CSI images 143 to 154 as a metabolite map.
Choline/N-Acetyl	Displays a map of the ratio of the N-acetyl, 143 to 154 region, to the choline, 64 to 74 region.
Startup	Displays the averaged, absolute pixel values over the region of 50 to 200. This is a good picture of the excited ROI.
Composite image	Signal from all spectrum.
Signal Over Noise Ratio	The amplitude of the N-acetyl peak divided by the variation of the noise region (range 0.4 to 0.9 ppm).

How Do I...

This section provides the step-by-step instructions for using FuncTool 2 to display a PROSE or PROBE sequence. Specifically, it describes how to:

- Display Images and Spectrums
- Display Regions of Interest

Display Images and Spectrums

Use this procedure to display the 3D PROSE or PROBE images that you obtained during scanning. The prerequisite for display is a valid image set of 3D spectroscopy images.

1. Click the **Display Desktop** icon.
2. Select your 3D series.
   - Located in the series section of your Browser.
   - This prepares the series for download into the FuncTool 2 display software.
3. Click **[FuncTool 2]**.
   - This launches your selected series into the FuncTool 2 software.
4. Select an appropriate localizer series.
5. Click **[OK]**.
   - This opens the Display Tool Command window.
   - The default format of the display window is the top two viewports displaying spectrums and the bottom two viewports displaying metabolite maps.

NOTE: Refer to the FuncTool 2 Performance User Guide for additional information on viewports and FuncTool display commands.

6. Click the appropriate icon to launch the metabolite map and spectrum display for the acquisition.
   - For PROSE, click **[Prostate]**.
   - For PROBE, click **[Brain]**.
   - This displays the metabolite maps and spectrum displays. The number of metabolite maps is defaulted to five: one single image (a composite map) and four other metabolite maps.
7. In the upper right viewport, change number of pixels to one.
   - This setting avoids cursor size smoothing.

Quick Steps: Display Images and Spectrums

1. Click the **Display Desktop** icon.
2. Select your 3D series.
3. Click **[FuncTool 2]**.
4. Select an appropriate localizer series.
5. Click **[OK]**.
6. Click the appropriate icon to launch the metabolite map and spectrum display for the acquisition.
7. In the upper right viewport, change number of pixels to one.
8. Right-click and select **Set X unit > ppm** to change the horizontal spectrum annotation in the upper right viewport from rank to ppm.
9. To toggle between a 1:1 and 1:4 image display, place the cursor over the viewport you want to change and press the **/** (forward slash) key.
10. To make a single spectrum display in the upper left viewport, click an ROI on one of the images.
11. To make a single spectrum in the upper right viewport, click the single spectrum on the left.

Quick Steps: Display Images and Spectrums

12. To select a different metabolite map, place the cursor over the red metabolite annotation, right-click and select a metabolite from the pull-down menu.
13. To adjust the window width and level of the localizer image, hold and press the **Ctrl** key while adjusting the width and level with the middle mouse button.
14. To page through the 3D images, place the cursor on the red slice location annotation, and click or right-click to navigate through the series.
15. Reset threshold if there is little to no color on the ratio map.
16. Right-click and select **Save View** to save an image/spectrum (if desired).

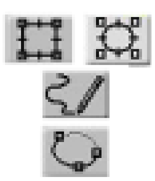
8. Right-click and select **Set X unit > ppm** to change the horizontal spectrum annotation in the upper right viewport from rank to ppm.
   - This displays the ppm scale below the spectrum, which designates the chemical address of each metabolite.
9. To toggle between a 1:1 and 1:4 image display, place the cursor over the viewport you want to change and press the **/** (forward slash) key.
10. To make a single spectrum display in the upper left viewport, click an ROI on one of the images.
11. To make a single spectrum in the upper right viewport, click the single spectrum on the left.
    - The advantage of viewing the spectrum in the upper right viewport is that it has the ppm horizontal scale.
    - As you move the cursor over the spectrum in the upper right viewport, the ppm that correlates with the vertical cursor position displays on the horizontal axis.
12. To select a different metabolite map, place the cursor over the red metabolite annotation, right-click and select a metabolite from the pull-down menu.
13. To adjust the window width and level of the localizer image, hold and press the **Ctrl** key while adjusting the width and level with the middle mouse button.
    - If the metabolite map width and level turn red or get significantly changed, to return to the default values, press the **W** key.
14. To page through the 3D images, place the cursor on the red slice location annotation, and click or right-click to navigate through the series.
15. Reset threshold if there is little to no color on the ratio map.
    a) Select **Prostate > Advanced Settings > Ratio > Custom**.
    b) Enter a value representing the baseline.
    c) Select **Save > Done > Compute > Close**.
16. Right-click and select **Save View** to save an image/spectrum (if desired).
    - This saves the image/spectrum in black and white for later viewing in the Viewer or Mini Viewer.

Display Regions of Interest

The ROIs displayed when you first enter a protocol represent the voxels from the acquired VOI. The size of the individual ROI is determined by the acquisition matrix.

Use this procedure to display regions of interest in spectroscopy images.

1. Place the cursor on an ROI and click to display a spectrum from an individual ROI.
2. Click and drag an individual ROI to move it to a new location.
3. Erase the ROI, if necessary.
   - To erase a single ROI, click to make it active and press the **Ctrl+X** keys.
   - To erase all the ROIs on the images, place the cursor outside the ROIs, press and hold the **Ctrl** key and click and drag a box around the ROIs. Press the **Ctrl+X** keys.
     – The box around the ROIs connects or groups the ROIs.
4. Click an ROI from the Display Tool Command window to deposit an ROI on all image viewports.



   ◆Choose a box or a circular ROI.

   ◆Choose the pencil for a free-hand ROI.

   ◆Choose spline to draw your own ROI shape.

   - ROIs are displayed on all images within the data set.
5. Click and drag any of the square handles on the ROI to re-size ROI coverage.
6. Click and drag the center ROI to reposition the ROI.
7. Toggle between splitting and merging ROIs.
   a) Connect the ROIs together by clicking and dragging a box around the ROIs.
   b) Click **[Split ROI]**.
      – This splits ROIs into multiple ROIs.

Quick Steps: Display Regions of Interest

1. Place the cursor on an ROI and click to display a spectrum from an individual ROI.
2. Click and drag an individual ROI to move it to a new location.
3. Erase the ROI, if necessary.
4. Click an ROI from the Display Tool Command window to deposit an ROI on all image viewports.
5. Click and drag any of the square handles on the ROI to re-size ROI coverage.
6. Click and drag the center ROI to reposition the ROI.
7. Toggle between splitting and merging ROIs.
8. Undo a split ROI.

8. Undo a split ROI.
   a) Connect the ROIs together by clicking and dragging a box around the ROIs.
   b) Click **[Merge ROI]**.
   - It is much easier to Merge ROIs and then delete them by pressing the **Ctrl+X** keys, rather than deleting each individual ROI.

Chapter 20

Imaging with ASSET

Introduction

Array Spatial Sensitivity Encoding Technique (ASSET) is an optional imaging feature that allows faster scanning when using the Torso Phased Array (PA) coil. It is designed to achieve the following benefits:

- reduced breath-hold time
- increased spatial resolution for a given scan time
- increased number of slices for a given scan time
- reduced blurring for compatible FSE family sequences

This chapter explains the characteristics of ASSET. It also explains the step-by-step instructions to help you learn how to:

- Acquire an ASSET Calibration Sequence
- Acquire an ASSET Imaging Sequence

In addition, this chapter answers the following questions:

1. What is ASSET?
2. When would I use ASSET?
3. What pulse sequences can I use with ASSET?
4. Which features are compatible with ASSET?
5. What is ASSET Calibration?

What Do I Need to Know About...

This section presents the concepts necessary to successfully understand imaging with ASSET. Specifically, you need to understand:

- ASSET Basics
  - Supported Features
- Scan Parameters
  - ASSET Calibration
  - ASSET Imaging
- Imaging Characteristics
- Applications

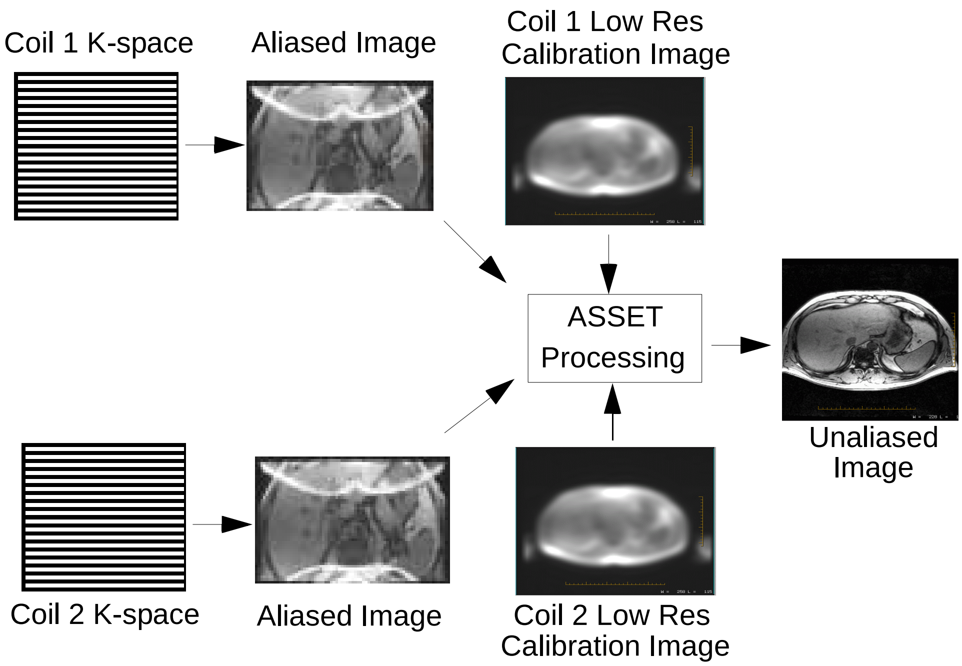
ASSET Basics

ASSET is a technique for reducing scan time when the Torso Phased Array (PA) coil is used. The reduction in scan time is due to every other line in K-space being skipped, while keeping the total area covered in K-space the same. A half phase field of view (0.5 PFOV) is an example of a technique that uses a similar principle. ASSET requires a calibration scan prior to the image acquisition. This calibration scan is required for the system to account for the phase wrapped or aliased anatomy that occurs within each coil in the phased array set. The calibration scan measures each receive coil's sensitivity (spatial image intensity weighting). These sensitivity maps are needed to unwrap the aliasing in the ASSET scan (Figure 20-1). The calibration acquisition takes approximately six seconds.

The aliasing occurs in an ASSET scan and not in a non-ASSET scan because the ASSET acquisition is, in effect, acquiring half the data in the phase FOV direction. Anytime there is anatomy outside the FOV in the phase direction, aliasing or wrap around occurs.

NOTE: At this time, ASSET Imaging is only compatible with the Torso PA coil.

Figure 20-1 ASSET Diagram

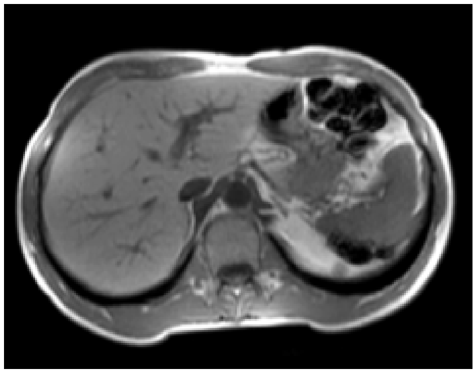


The receive coil sensitivities must be measured in a separate acquisition, called ASSET Calibration before any ASSET image acquisitions are performed. The information obtained during ASSET calibration is stored and used throughout the patient's exam. You only need to perform the ASSET Calibration once for your entire exam. However, you may acquire more, if the scanning ranges change considerably throughout your exam. If more than one calibration is done, the data is used from the most recent calibration scan. Once you have ended the exam, the ASSET calibration information is discarded. ASSET Calibration images are saved as a separate series and can be recalled from the Browser.

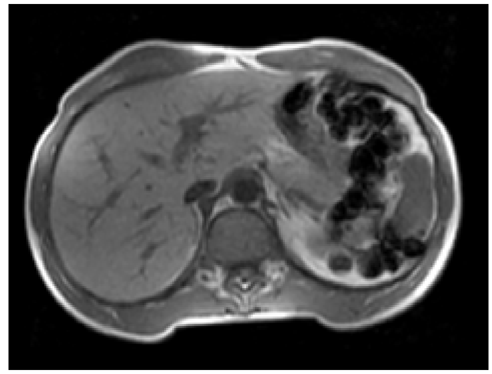
NOTE: If another exam is performed on the same patient, another ASSET Calibration must be performed.

In Figure 20-2, Fast Gradient Echo (GRE) images are shown with and without the use of ASSET. Both images were acquired with the same scan parameters, but note the scan acquired with ASSET was imaged in half the time.

Figure 20-2 Conventional Fast GRE vs. Fast GRE with ASSET



Without ASSET
Scan Time = 16 Sec.



With ASSET
Scan Time = 8 Sec.

NOTE: The scan parameters used in Figure 20-2: 2.3 Time to Echo (TE), 62 bandwidth (RBw), 15 slices, 8 mm thick, 2 mm space, 34 FOV, 26 phase FOV, 256x128 matrix with 1 number of excitations (NEX).

Supported Features

The ASSET option is available only when using the Torso PA coil and can be used with the following pulse sequences:

- 2D Fast Gradient Echo (Fast GRE)
- 2D Fast SPoiled Gradient Echo (Fast SPGR)
- 3D Gradient Echo (GRE)
- 3D SPoiled Gradient Echo (SPGR)
- 3D Fast Time of Flight Gradient Echo (Fast TOF GRE)
- 3D Fast Time of Flight Spoiled Gradient Echo (Fast TOF SPGR)
- Single Shot Fast Spin Echo (SSFSE)
- Fast Spin Echo-Accelerated (FSE-XL)
- 2D or 3D Fast Recover Fast Spin Echo-Accelerated (FRFSE-XL)

NOTE: For the FSE-XL and FRFSE-XL pulse sequences, time reduction depends on the choice of ETL, phase FOV, NEX, and matrix.

Only 2D Fast GRE and 2D Fast SPGR pulse sequences are compatible with ASSET calibration. After the calibration scan is acquired, any of the ASSET pulse sequences can use the calibration data to perform the ASSET image acquisitions. ASSET calibration images are annotated “CAL” in the lower left corner of display screen. These images are not clinically diagnostic and are not recommended for filming. Images acquired during

ASSET imaging are annotated “AST” in the lower left corner of display screen. In addition, ASSET is compatible with the features listed in Table 20-1.

Table 20-1 ASSET Compatibility. The X denotes the PSD is compatible with the Imaging Option and ASSET.

Imaging Option	SSFSE	FRFSE-XL	FSE-XL	FGRE/ FSPGR	FTOF GRE/SPGR
Flow Compensation	X	X	X	X	
POMP					
Square Pixel					
Resp Comp					
Mag Transfer					
Cardiac Gating/Trig	X	X	X	X	X
Tailored RF		X	X		
De Prepared				X	
Full Echo Train		X	X		
ZIP 1024					
ZIP x 2		X (3D)		X (3D)	X
Smart Prep					X
Multi Station					X
T2 Prep					
Phase Sensitive					
ASSET Calibration					
Variable Bandwidth	X	X	X	X	X
No Phase Wrap					
EDR	X	X	X	X	X
SCIC	X	X	X	X	X
Classic		X			
Sequential	X	X	X	X (2D)	
Resp Gate/Trig	X	X	X		X
IR Prepared				X	X
Multi Phase				X	X
CCOMP					
ZIP 512	X	X	X	X	X

Imaging Option	SSFSE	FRFSE-XL	FSE-XL	FGRE/ FSPGR	FTOF GRE/SPGR
ZIP x 4		X (3D)		X (3D)	X
Blood Suppression			X		
Real Time					
Spectral Spat. RF					
Navigator					
Fluoro Trigger					
Fat/Water SAT	X	X	X	X	X
SPECIAL				X (3D)	X
Fractional NEX*	X	X	X	X	X
Fractional Echo*				X	X
PFOV in steps of 0.1	X				X
Oblique	X	X	X	X	X
Spatial SAT	X	X	X	X	X

NOTE: *Fractional echo and fractional NEX are not compatible; only one of the two can be used within a series prescription.

Scan Parameters

Scan parameters most often changed with ASSET are divided into three sections: Scan Timing, Acquisition Timing, and Scanning Range parameters. Selection of these parameters can vary for each acquisition and between ASSET calibration and ASSET imaging acquisitions.

ASSET Calibration

You must select the ASSET Calibration Imaging Option, located on the Imaging Options window, in order to perform this acquisition. During ASSET calibration, several scanning parameters are not selectable. The only selectable scan parameters are plane, PSD, slice thickness, and slice locations. The calibration data must cover the scanning range of the ASSET image acquisition. Therefore, prescribe the ASSET Calibration scanning range from posterior to anterior, the right to left, or the inferior to superior borders of the anatomy. ASSET Calibration FOV is set at 48 cm, and can not be changed.

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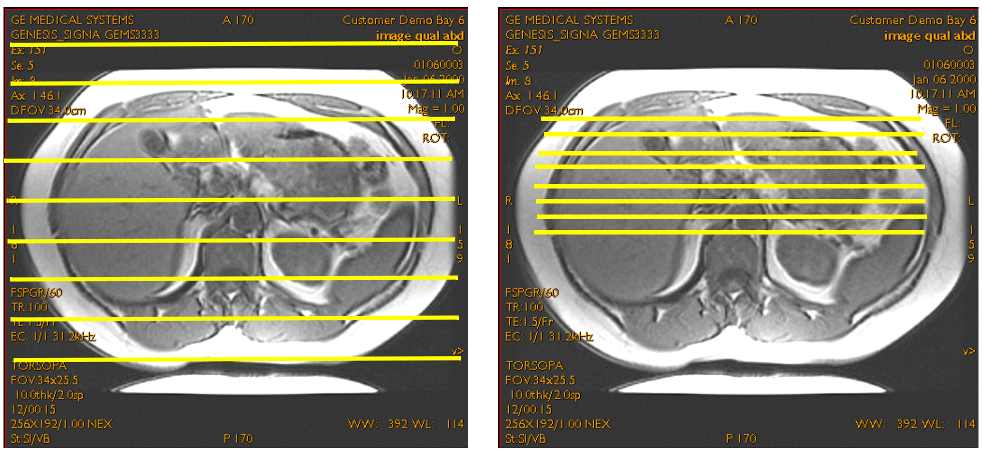
ASSET Imaging

Selection of scanning and acquisition parameters should be chosen to best display your desired imaging anatomy. You must select **ASSET** on the Imaging Options window in order to perform any acquisition using ASSET.

NOTE: Refer to the Signa® Infinity with Signa Select (ASP2)™ guide for additional information about the compatible pulse sequences.

The scanning range of the ASSET image acquisition must be within the borders of the scanning range used for the ASSET Calibration acquisition. Scan regions that fall outside of the calibration volume are blank in the final images. Figure 20-3 provides an example of an acceptable scanning range.

Figure 20-3 ASSET Calibration and ASSET Imaging Scanning Range



ASSET Calibration Scanning Range   ASSET Imaging Scanning Range

ASSET is compatible with oblique imaging, although as the oblique angle increases, the potential for aliasing increases.

Imaging Characteristics

ASSET does not change the characteristics of the compatible PSDs. The primary applications for using the ASSET option include:

- Decreased scan time
  - For example, scan time decreases with the use of a smaller phase FOV.
  - Scan time for the FSE PSDs may not decrease for all combinations of scan parameters that typically affect scan time. For example, with some combinations of ETL and PFOV selections, changing the phase matrix value does not change scan time.
  - An even ETL should be prescribed for all FSE PSDs when using ASSET.

- Increased resolution
  - For example, you can increase the spatial resolution by selecting a larger phase matrix, with the same scan time when compared to images acquired without using ASSET.
- Increased number of slices
  - For example, if your scan time of 15 seconds allows 6 slices, selecting ASSET decreases the scan time. Therefore, increasing the number of slices and moving into a dual acquisition allows more slices within the same 15 second breath-hold.
- Reduced blurring in the FSE family of ASSET compatible PSDs
  - ASSET allows a lower ETL selection for FSE-XL and FRFSE-XL while keeping the scan time the same as a non-ASSET scan.
  - SSFSE scans with ASSET exhibit reduced blurring versus non-ASSET SSFSE images.

Everything in Magnetic Resonance Imaging (MRI) has a trade-off. ASSET's trade-off is the notable decrease in signal to noise ratio (SNR). When comparing two images acquired with and without the ASSET option, the ASSET images have an SNR loss comparable to halving the NEX (slightly more than a 40% loss). In examinations with high signal, such as a Contrast Enhanced Magnetic Resonance Angiography (CEMRA) exam, the SNR effects are rarely noticed. Keep in mind the image quality trade-offs listed in Table 20-2, if you need to regain SNR that is reduced when ASSET is turned on.

Table 20-2 Imaging Effects

Parameters	Image Effect			
	Echo Spacing	SNR	Resolution	Scan Time
Gradient Slew Rate ⇑	⇓	N/A	*	*
Receive Bandwidth ⇑	⇓	⇓	*	*
Frequency Matrix ⇑	⇑	⇓	⇑	**
Phase Matrix ⇑	N/A	⇓	⇑	⇑
FOV ⇑	⇓	⇑	⇓	**
Phase FOV ⇑	N/A	⇑	N/A	⇑
NEX ⇑	N/A	⇑	N/A	⇑

NOTE: *There is not always a direct correlation.

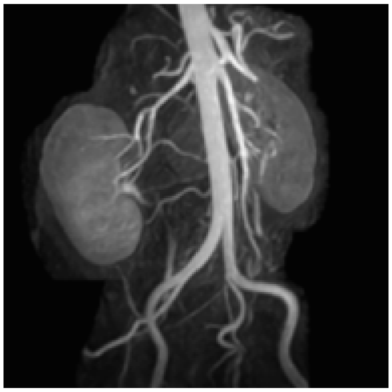
**There is no effect on Scan Time unless the TR is increased.

Applications

ASSET is currently used for body applications. These body applications include abdomen and chest imaging, as well as breath-held angiography studies.

An example of a 13 second Renal CEMRA acquisition using ASSET is shown in Figure 20-4.

Figure 20-4 ASSET CEMRA



ASSET is not appropriate for all imaging applications, only those that require more speed, have SNR to spare, and cannot employ other techniques.

How Do I...

This section provides the step-by-step instructions for performing an ASSET acquisition. Specifically, it describes how to:

- Acquire an ASSET Calibration Sequence
- Acquire an ASSET Imaging Sequence

Acquire an ASSET Calibration Sequence

ASSET calibration sequences must be performed prior to any sequences using the ASSET feature. This sequence acquires the data necessary for effectively performing ASSET imaging.

Use this procedure to set up and scan an ASSET calibration sequence. These images are not to be used for clinical diagnostic purposes and are not recommended for filming.

1. Acquire a 3-Plane Localizer series.
   - Make sure the localizer covers the desired anatomy.
2. Click **[New Series]**.
3. Select **Coil > Torso PA**.
   - ASSET is only compatible with the Torso PA coil, at this time.
4. Select **Plane > Axial**.
   - ASSET calibration is compatible with any imaging plane.
5. Select **Mode > 2D**.
   - ASSET calibration is only compatible with 2D mode.
6. Select a **Fast GRE** or **Fast SPGR** pulse sequence.
   - ASSET calibration is only compatible with FGRE and FSPGR.
   - Applicable series in the GE Protocols are Abd/Lumbar and ASSET Abdomen.
7. Select **Grad Mode > Whole**, if applicable.
   - ASSET Calibration is compatible with the Whole Body gradient mode.
   - The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.
8. Select the **ASSET Calibration** Imaging Option.
   - This imaging option must be selected in order to perform this sequence.
   - This is the only imaging option compatible with ASSET Calibration.

Quick Steps: Acquire an ASSET Calibration Sequence

1. Acquire a 3-Plane Localizer series.
2. Click **[New Series]**.
3. Select **Coil > Torso PA**.
4. Select **Plane > Axial**.
5. Select **Mode > 2D**.
6. Select a **Fast GRE** or **Fast SPGR** pulse sequence.
7. Select **Grad Mode > Whole**, if applicable.
8. Select the **ASSET Calibration** Imaging Option.
9. Enter the Scanning Range parameters.
10. Graphically prescribe your desired scan locations.
11. Click **[Save Series]** to close the prescription.
12. Click **[Prepare to Scan]** to download the ASSET Calibration sequence.
13. Click **[Auto Prescan]** to ready the system for data acquisition.
14. Give your patient breath holding instructions.
15. Click **[Scan]** to initiate the ASSET Calibration acquisition.

9. Enter the Scanning Range parameters.
   - Choose your locations to optimize your desired anatomy coverage.
     – Typically an 8 mm slice thickness provides enough slices within a single acquisition to cover the scanning range form one border of the anatomy to the opposite border of anatomy (left to right, anterior to posterior, or inferior to superior). If not, increase the slice thickness until the prescription is a single acquisition.
10. Graphically prescribe your desired scan locations.
    a) Click the **Graphic Rx** Icon in the Additional Parameters area.
    b) Select the desired localizer image to prescribe your imaging slices.
    c) Press the **Shift** key and click to deposit the starting slice.
    d) Click and drag the add handle to increase the number of slices.
       – Prescribe enough slices to cover from one border of the anatomy to the opposite border of anatomy. Extend beyond the anatomical borders to ensure complete coverage. This ensures you can place your ASSET image prescription anywhere on the localizer and there will be a CAL file available.
       – Maximum number of slices is 128.
    e) Adjust the prescription as necessary.
    f) Click **[Accept]** to register the slice locations for the current acquisition.
       – Location values are displayed in the Scanning Range area.
11. Click **[Save Series]** to close the prescription.
12. Click **[Prepare to Scan]** to download the ASSET Calibration sequence.
13. Click **[Auto Prescan]** to ready the system for data acquisition.
14. Give your patient breath-holding instructions.
    - Use the same breath-hold instructions that will be used in the ASSET image acquisition.
15. Click **[Scan]** to initiate the ASSET Calibration acquisition.

Acquire an ASSET Imaging Sequence

ASSET is an imaging technique used for rapid breath-held scanning. Specific applications are rapid liver imaging and contrast enhanced renal MRA studies.

Use this procedure to set up and scan an ASSET imaging sequence. ASSET imaging sequences are only to be performed proceeding an ASSET calibration acquisition.

1. Click **[New Series]**.
2. Select **Coil > Torso PA**.
   - ASSET is only compatible with the Torso PA coil.
3. Select **Plane > Axial**.
   - ASSET imaging is compatible with any imaging plane.
4. Select **Mode > 2D** or **3D**.
   - ASSET imaging is only compatible with 2D and 3D modes.
5. Select any ASSET compatible pulse sequence.
6. Select **Grad Mode > Whole**, if applicable.
   - ASSET is compatible with both gradient modes.
   - The **Grad Mode** text box is only available on Twin*Speed*™ Resonance Module (TRM) systems.
7. Select the **ASSET** Imaging Option.
   - You must select this imaging option in order to perform an ASSET acquisition.
8. Enter the Imaging Parameters.
   - The parameters should reflect the specific protocol tailored to the current imaging examination.
   - For specific exam protocols refer to either your site tailored protocols or GE pre-loaded protocols.

Quick Steps: Acquire an ASSET Imaging Sequence

1. Click **[New Series]**.
2. Select **Coil > Torso PA**.
3. Select **Plane > Axial**.
4. Select **Mode > 2D** or **3D**.
5. Select any ASSET compatible pulse sequence.
6. Select **Grad Mode > Whole**, if applicable.
7. Select the **ASSET** Imaging Option.
8. Enter the Imaging Parameters.
9. Graphically prescribe your desired scan locations.
10. Click **[Save Series]** to close the prescription.
11. Click **[Prepare to Scan]** to download the ASSET imaging acquisition.
12. Click **[Auto Prescan]** to ready the system for data acquisition.
13. Give your patient breath holding instructions.
14. Click **[Scan]** to initiate the ASSET imaging acquisition.

9. Graphically prescribe your desired scan locations.
   a) Click the **Graphic Rx** Icon in the Additional Parameters area.
   b) Select the desired localizer image to prescribe your imaging slices.
   c) Press the **Shift** key and click to deposit the starting slice.
   d) Click and drag the add handle to increase the number of slices.
      – Slice locations should be within the imaging range of the ASSET Calibration series.
      – Maximum number of slices is 128.
   e) Adjust the prescription as necessary.
   f) Click **[Accept]** to register the slice locations for the current acquisition.
      – Location values are displayed in the Scanning Range area.
10. Click **[Save Series]** to close the prescription.
11. Click **[Prepare to Scan]** to download the ASSET imaging acquisition.
12. Click **[Auto Prescan]** to ready the system for data acquisition.
13. Give your patient breath-holding instructions.
    - Use the same breath-hold instructions that you used in the ASSET Calibration acquisition.
14. Click **[Scan]** to initiate the ASSET imaging acquisition.

Chapter 21

High Order Shim

Introduction

The High Order Shim feature allows you to shim over a region-of-interest (ROI) taking advantage of the High Order Shim coils. This feature is likely to improve the local field homogeneity for use in applications such as fat suppression, spectroscopy, spiral scanning, and functional imaging.

This chapter explains the characteristics of High Order Shim. It also explains the step-by-step instructions to help you learn how to:

- Scan a High Order Shim Series
- Calculate the Shim

In addition, this chapter answers the following questions:

1. What is the High Order Shim feature?
2. When would I use High Order Shim?
3. What are the available shim series?
4. How can I identify if the shim has improved?
5. What are some applications for High Order Shim?

What Do I Need to Know About...

This section presents the concepts necessary to successfully understand the High Order Shim feature. Specifically, you need to understand:

- High Order Shim
  - Available Shim Series
  - Autoshim Button
- Shimming Process
  - Selecting a Region of Interest
  - Shim Improvement Identification
  - Shim Calculation Failures
  - Advanced Window
  - Library Window
- High Order Shim Notes
- Recommendations

High Order Shim

The High Order Shim process is run as another series in the exam prior to the main clinical series. It allows you to shim over a region-of-interest (ROI) to take advantage of the High Order Shim coils. High Order Shim is likely to improve the local field homogeneity. The following sections describe the basic routine for in-vivo high order shimming with a patient, and additional parts with a brief explanation of the options available in each window. Currently, there is a specific order of steps that need to be followed to use the shim process in regards to the shim series capturing any S/I FOV offset that may occur between the localizer series and subsequent clinical series. This process is explained in the **How Do I ...** section of this chapter.

Available Shim Series

There are four shim series available defined by the field of view (FOV) and gradient mode. The 48 cm FOV series is primarily used in the body coil, but can also be used for receive only surface coils and for small volume T/R coils that are off-center, such as the wrist or knee coils. For use with the volume T/R coils, you may want to update the coil used after selecting the head shim series to benefit from the increased SNR.

The 24 cm FOV series is used primarily for the head coil and can also be used for the knee T/R volume coil if the knee is positioned at isocenter. Anything outside the 24 cm region at isocenter must be shimmed with the 48 cm series.

To use the 24 cm FOV shim series for a coil other than the head coil, select the series matching the gradient mode you will use in the next clinical series and then change the patient orientation and coil name to match.

Choose the gradient mode in the **Grad Mode** text box to match with that defined in the clinical series just saved. In the event of a mis-match, a message to this effect is given upon saving the High Order Shim series.

Autoshim Button

Anytime you enable the **[Autoshim]** button after running a High Order Shim series, the following message appears:

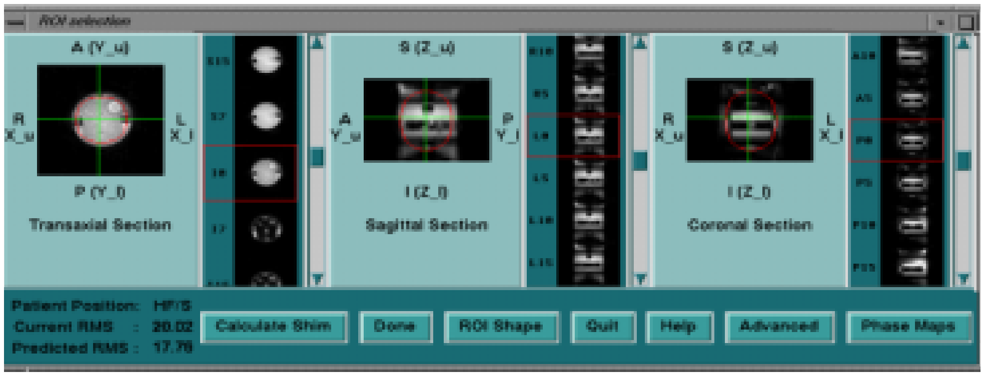
> "You have set ON the autoshim button after having run the high order shim calibration. If this remains ON, scanning with this series resets ALL the shim coils."

This is telling you all the shims channels will be reset to zero as if you had never run the shim series. Reselecting the **[Autoshim]** button should be done anytime you change locations in the anatomy that are outside the previously shimmed volume or that will cause the table to move due to a new S/I offset. A new shim series should also be performed for any new slices prescribed that will fall outside the previously selected shim ROI even if an S/I table movement is not required. This is due to the fact that ONLY the region inside the ROI used in the last shim series is shimmed.

Shimming Process

After the shim scan and reconstruction finishes, the Shim User Interface appears (Figure 21-1).

Figure 21-1 Shim User Interface (ROI Selection Window)



NOTE: The processing and displaying times of this interface are a function of the High Order Shim series used, and may take many seconds to appear. The 24 cm FOV series processing only takes 5 to 10 seconds, whereas the 48 cm FOV series takes 30 to 45 seconds before the shim interface appears.

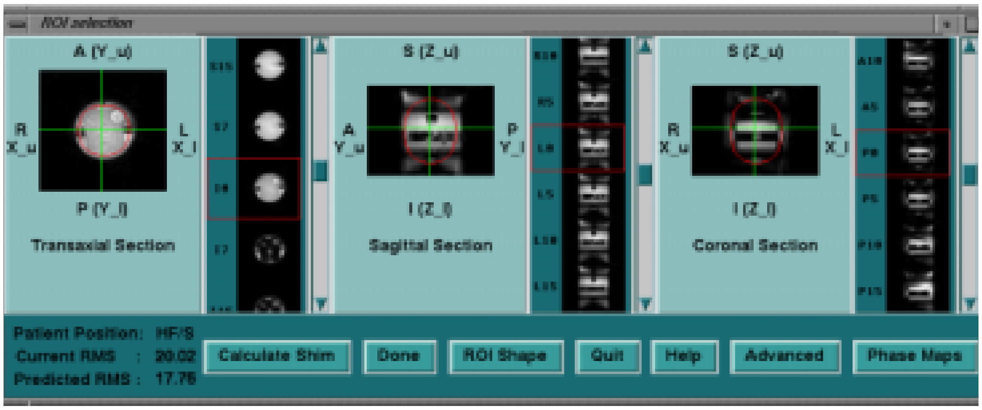
The Shim User Interface is where the action of defining a specific region to shim takes place. Only the region inside the ROI used in the shim series is shimmed, given the patient has not been moved. Anatomy outside the region selected for shimming may be adversely affected by the shim process and may cause image distortions and artifacts. The High Order Shim process is for improving localized areas of anatomy to correct for affects of the patient in the magnetic field. This process improves further upon the capabilities of the current Autoshim process but only in the area selected by the ROI in the shim user interface. The shim of the regions surrounding the ROI is sacrificed in order to allow the area inside the ROI to be further improved. It is important to insure the ROI selected covers the slices desired in the following series.

Selecting a Region of Interest

For selecting the ROI, you can select any slice from the corresponding scrollbar in each direction. The slice may also be selected by using the two green intersection lines on each of the three images (axial, sagittal, and coronal). The selected ROI may be either rectangular or elliptical.

You may drag and resize the ROI on any image. The ROI displayed on the other two images updates accordingly.

Figure 21-2 ROI Selection Window



In the ROI Selection window (Figure 21-2), you may select any of the features listed in Table 21-1 by clicking on the appropriate button.

Table 21-1 ROI Selection Window Features

Feature	Description
Green lines	Allows you to off-center the intersection between all three displayed images.
[Calculate Shim]	Runs the shim values calculation with the current ROI selection.
[Done]	Downloads the calculated values to the Shim supply and exits.
[ROI Shape]	Allows you to select between a rectangular and an oval shape ROI.
[Quit]	Exits without downloading.
[Help]	Includes instructions for manipulating the ROI and the green lines, as follows: • You may change the ROI shape by clicking the **[ROI Shape]** button, then selecting either rectangle or oval. • You may move the ROI by placing the cursor inside the ROI and dragging. • You may resize the ROI by placing the cursor outside the ROI and dragging. • You may move the intersecting planes one by one by placing the cursor on one of the green lines outside the ROI and dragging.
[Advanced]	Opens the Advanced window for additional choices.

Feature	Description (Continued)
[Phase/Magnitude Maps]	Allows you to toggle between displaying phase or magnitude images. The Phase Maps can help identify the location of off-center anatomy such as knees, wrists or shoulders. Small regions show up as small objects and are difficult to see in the large FOV shim series. The phase maps can help in locating a suitable ROI around the anatomy.

Shim Improvement Identification

To identify the improvement in the shim of the ROI selected, look at the RMS deviation current and predicted areas in the ROI Selection window after positioning the ROI and selecting the **[Calculate Shim]** button. The current area tells you what the shim is now and the predicted gives you a sense of how much it might improve after Done/Download is run. Any shifting by the patient makes the results shift. Generally, if the predicted value is close to the current value (within 1 to 2 Hz,) then there is very little benefit in running another iteration. Generally, only one or two iterations should be necessary.

If there seems to be little to no improvement for the very first pass, clicking the **[Advanced]** button opens the Advanced window and allows you to make sure all shim coils are enabled for use on the right hand side. This is evident by seeing that the buttons next to each coil is indented (selected), if not, then select them all and calculate the shim again. The buttons stay enabled until someone manually disables them. Refer to Figure 21-3 for the Advanced window and coil buttons.

Shim Calculation Failures

If the shim calculation fails, an error message appears stating, "SVD error: not enough points". This is telling you that the software could not identify enough data points within the ROI that are above a certain pixel intensity threshold to be used in the calculation of the new shim settings.

Possible causes:

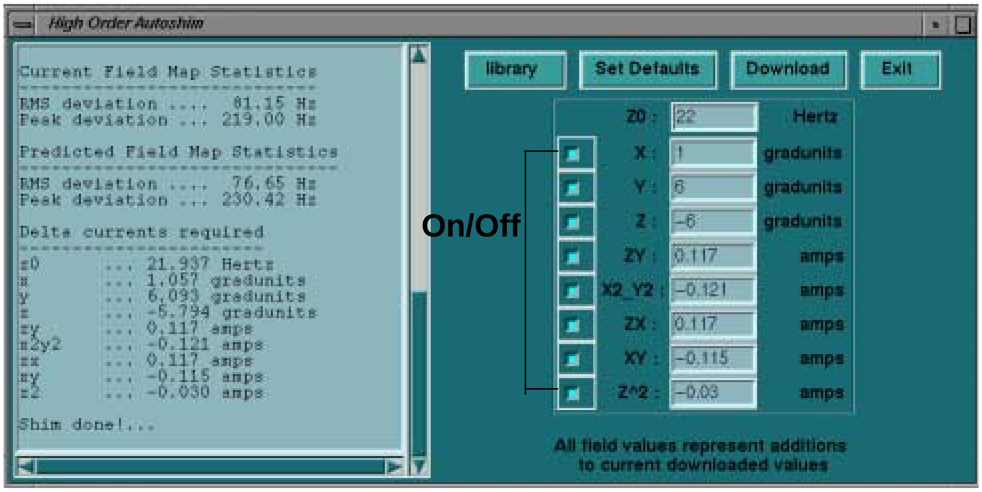
- The image is very dark, i.e., not enough signal.
  - It may be possible to fix this by exiting the shim interface, running autoprescan again, entering manual prescan and increasing the R1 receive gain by 1 or more counts while looking at the Scan TR entry point. You may also use the R2 gain if R1 is at maximum. If this does not help, then the anatomy currently being imaged is not able to be shimmed.

- The ROI contains too much of the background inside the ROI boundaries.
  - Check the ROI size and position, shifting and repositioning as necessary. Clicking **[Calculate Shim]** repeatedly during this process lets you know when the problem is corrected sufficiently to provide shim information.
- The patient is causing a severe shim distortion.
  - This may occur for many reasons such as imaging near metal implants that cause RF reflection. Clicking **[Phase Maps]** from the shim interface can help identify this issue. You will see white and black stripes side by side inside the ROI if there are severe shim distortions. The shim option is not able to correct for shim distortions that are this severe.

Advanced Window

Clicking the **[Advanced]** button in the ROI Selection window (Figure 21-2) allows you to review details of the shim calculation results, save a shim-set of data, recall a previously saved set, manually enter values, or remove one or more of the shim channels.

Figure 21-3 Advanced Window



In the Advanced window (Figure 21-3), you may select any of the features in Table 21-2 by clicking the appropriate button.

Table 21-2 Advanced Window Options

Option	Description
Log Window	Allows you to review a log of the shim calculation and download details. An estimate as to the quality of the improvement after the channels are updated can be seen by looking at the change in RMS deviation between the Current and Predicted Map statistics.
[library]	Opens the Library window, to either save a shim-set or recall a previously saved one.
[Set Defaults]	Allows you to select a set of predefined shim values, corresponding to resetting the linear shims to the original system LVShim values, and with high order shim channels set to zero.
[Download]	Loads the current set of shim values to the Shim supply.
[Exit]	Returns to the basic window.
On/Off	Allows you to remove a linear and/or high order shim channel from the current shim set, i.e., not use it for updating the calculation or downloading to the shim supply. More than one can be removed for this purpose. The default for each channel is ON.
Field text boxes	Allows you to manually enter the difference value to be added to each channel or the system automatically enters values after calculating the shim.

Field range of values (Table 21-3) are suggested ranges for each channel based on expected changes in field homogeneity, and are not necessarily typical values.

The numbers in each channel are add-on values to whatever is already in that channel. Hence any positive or negative value within the ranges defined is valid. Typical values are below +/- 0.100A, with less than +/- 0.010A considered negligible.

Table 21-3 Field Range of Values

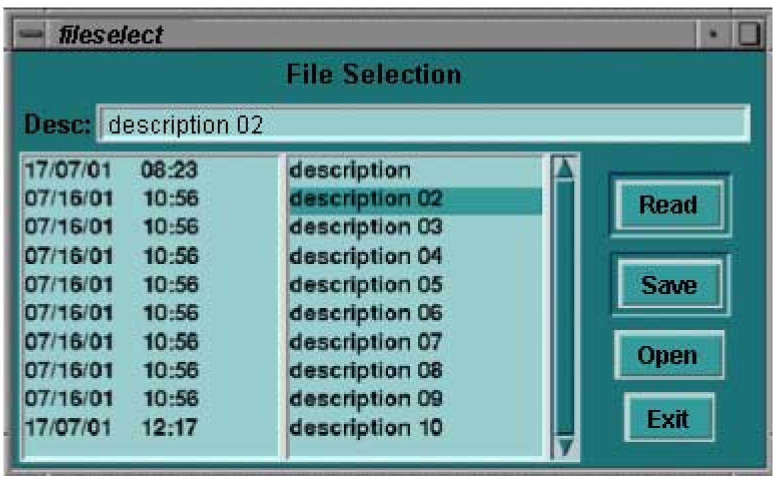
Channel	Units	Negative Limit	Positive Limit
Z_0	Frequency in Hertz	-500	+500
X	Linear shim in grad units	-20	+20
Y	Linear shim in grad units	-20	+20
Z	Linear shim in grad units	-20	+20
ZY	High order shim in A	-.500	+.500

Channel	Units	Negative Limit	Positive Limit
X^2_Y^2	High order shim in A	-.500	+.500
ZX	High order shim in A	-.500	+.500
XY	High order shim in A	-.500	+.500
Z^2	High order shim in A	-.250	+.250

Library Window

Clicking the **[library]** button, in the Advanced window (Figure 21-3), allows you to save a shim-set of data, recall a previously saved set, or manually adjust a previously saved set.

Figure 21-4 Library Window (File Selection Window)



In the Library window (Figure 21-4), you may select any of the features listed in Table 21-4 by clicking on the appropriate button.

Table 21-4 Library Window Options

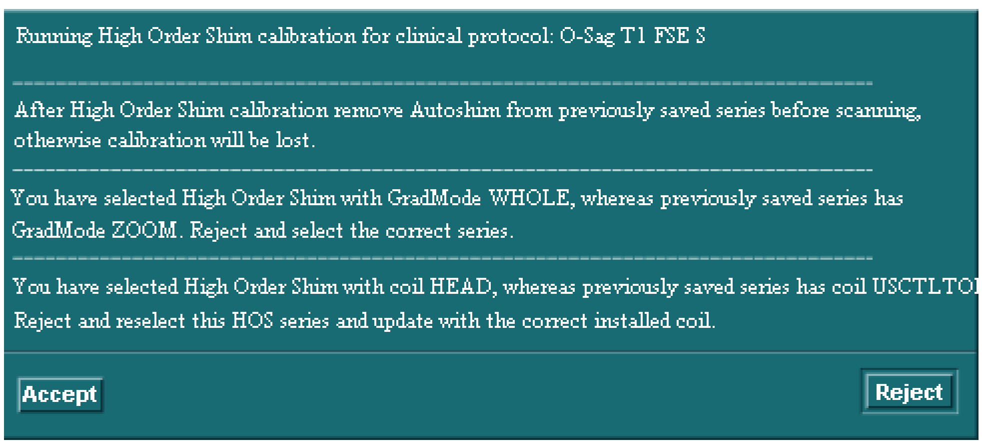
Option	Description
Desc:	Allows you to give the new file a description, which appears in the list in place of the current description line. The first line is reserved for the default linear shim values.
[Read]	Allows you to read the current set of shim values from the shim supply and linear shims, and present the difference between these and the highlighted set in the Library in the Advanced window.
[Save]	Saves the currently displayed set of shim values to the selected description file.

Option	Description (Continued)
[Open]	Opens an editor with a previously saved set of shim values, which are afterwards read in as the difference between these values and the currently downloaded set.
[Exit]	Returns you to the Advanced window.

High Order Shim Notes

- The shim series takes up an Exam series number but does not place any images in the database. When looking at the Browser listing, it will be evident as a missing series. A series may also be missing from an Exam if the series was purposely deleted.
- Use as large an ROI as practical for the anatomy to be shimmed. The larger the area, the better the chance of improving the overall shim. Effectiveness becomes reduced for smaller ROIs due to limited data points for the software to distinguish between shim coils for corrections.
- If you choose to run a shim series as the first series in an exam the confirmation message in Figure 21-5 appears:

Figure 21-5



This message may also appear for the very first shim series after the System software has been started even if the shim series is not the first series. This is a known issue and is currently being investigated.

- There is a 6 second delay in the start of Autoprescan for any series that has changed the gradient mode or has AutoShim selected due to the shim feature making sure the High Order Shim coils are reset to zero current.
- If you change the coil selection used for any High Order Shim series, make sure the Frequency Direction in the Acquisition Timing area is set to A/P prior to saving the shim series. If the selection is changed from

the default Head or Body coil, the frequency direction may automatically change, causing the images displayed in the High Order Shim user interface to rotate by 90 degrees with respect to the annotation. This only affects the image orientation in the shim display and not the following clinical images.

- Do not change any parameter in the shim series other than coil name discussed elsewhere.
- Do not use the GRx box to change slice locations in the shim series.
- Do not use the download button in the Advanced UIF screen more than once per scan. The **[Calculate Shim]** button can be used as many times as necessary while changing ROI positioning/shape, but only download once.
- Do not Copy/paste any shim series. Always pull in a new copy from the GE/other saved protocol HighOrderAutoshim.

Recommendations

The recommended occasions when High Order Shim calibration should be rerun are:

- Change in gradient mode
- Change in table position
- Change in region to be high order shimmed
- When results are not as expected, such as the RMS current value being higher than the last shim iteration during the same shim series.

How Do I...

This section provides the step-by-step instructions for High Order Shimming. Specifically, it describes how to:

- Scan a High Order Shim Series
- Calculate the Shim

Scan a High Order Shim Series

The High Order Shim feature allows you to shim over a ROI taking advantage of the High Order Shim coils. This process is run as another series in the examination, prior to the main clinical series.

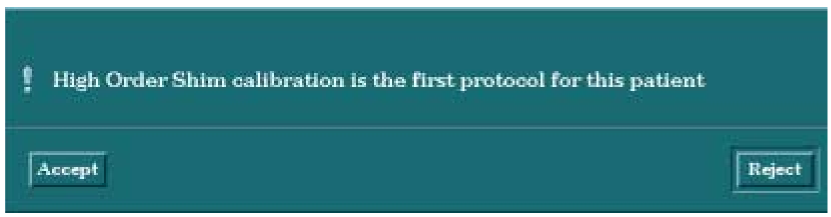
Use this procedure to run high order shimming with a patient.

1. Prescribe and run a localizer series.
   - Perform this series as normally done.
2. Prescribe and run any other series that you wish to run prior to specific localized shimming.
   - You may also just go right to the shim series.
3. Prescribe and save the clinical series you wish to run following the shim series before pulling in the shim series.
   - Remember to turn off the **Autoshim** option in this series since the High Order Shim takes precedence. Make sure there is a series description for each series used.
   - The High Order Shim series uses the series description as shown in step 6. (Further notes regarding the protocol Autoshim button are found below in the section "Autoshim Button")
4. Choose one out of the four series from the GE/other/HighOrderAutoshim protocol.
   - The choice depends on the expected maximum FOV (<24 cm or <48 cm) and the gradient coil (WB for WHOLE-BODY or ZM for ZOOM) to be used during clinical scanning.
5. Change the patient position parameters and RF coil to match those of the clinical series to be run next.
   - This High Order Shim scan should be run just prior to the actual clinical series, but after having saved the clinical series.
   - A change in the gradient coil used and/or cradle location for other series with the same patient requires a rerun of the High Order Shim scan.

Quick Steps: Scan a High Order Shim Series

1. Prescribe and run a localizer series.
2. Prescribe and run any other series that you wish to run prior to specific localized shimming.
3. Prescribe and save the clinical series you wish to run following the shim series before pulling in the shim series.
4. Choose one out of the four series from the GE/other/HighOrderAutoshim protocol.
5. Change the patient position parameters and RF coil to match those of the clinical series to be run next.
6. Save the series without changing any of the scan parameters other than those mentioned in the previous step.
7. If this information matches, then click **[Accept]** and **[Prep Scan]**.
8. Press **Advance to Scan** to move the table to the new position.
9. Run the shim series and complete the High Order Shim calibration.
10. Prep and run the previously saved clinical series.

6. Save the series without changing any of the scan parameters other than those mentioned in the previous step.
    - At this point the shim series gives you the following message with the choices of accept or reject: "Running High Order Shim calibration for clinical protocol: Saved series description here."
    - Other messages also appear in the same message pop-up window if there is any conflict identified between the clinical series and the shim series, such as the gradient mode and RF coil used do not match the subsequent series to be scanned.



7. If this information matches, then click **[Accept]** and **[Prep Scan]**.
    - If not, then click **[Reject]** and pull in a new shim series and make the appropriate modifications.
8. Press **Advance to Scan** to move the table to the new position.
9. Run the shim series and complete the High Order Shim calibration.
10. Prep and run the previously saved clinical series.
    - No cradle movement should occur at this time.
    - If you did not deselect Autoshim previously, use the view/edit feature to deselect autoshim, then save the series and proceed with the scan.

Calculate the Shim

Calculate the shim to run the shim values calculation with a specific ROI selected. This helps you to identify the improvement in the shim if the selected ROI.

Use this procedure to calculate the shim.

1. Place an ROI on the image.
   - The selected ROI may be rectangular or elliptical.
2. Manipulate the ROI on the images so that it occupies the desired region.
3. Click **[Calculate Shim]**.
   - The optimum values to improve the magnet homogeneity within the specified ROI volume are calculated.
   - The results are shown as the current and predicted RMS.
   - When the calculation is complete, the **[Done]** button highlights.
4. Make any ROI size/position changes and recalculate the shim, if necessary.
   - Any changes and subsequent "Calculate Shim" requests must be done prior to clicking the **[Done]** button.
5. Click **[Done]**.
   - At this point, the new values for the central frequency and linear shims are transferred to the system, and the five high order shim currents are downloaded to the shim supply channel by channel.
   - Once the download is complete, the High Order Shim interface closes.
6. If required, click **[Scan]** to check the shim corrections by running the shim scan again.
   - Ensure prior to any scanning that the High Order Shim windows have been closed (the High Order Shim windows remain open after download when this action is run from the Advanced window).
7. When the User Interface comes up again, click **[Calculate Shim]** and verify that the current RMS value has improved.
   - Refer to the section "Shim Improvement Identification" for details.

Quick Steps: Calculate the Shim

1. Place an ROI on the image.
2. Manipulate the ROI on the images so that it occupies the desired region.
3. Click **[Calculate Shim]**.
4. Make any ROI size/position changes and recalculate the shim, if necessary.
5. Click **[Done]**.
6. If required, click **[Scan]** to check the shim corrections by running the shim scan again.
7. When the User Interface comes up again, click **[Calculate Shim]** and verify that the current RMS value has improved.

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Appendix A

MR Compatibility Test Guidelines for the Signa System

Scope and Summary

Introduction

The document describes a set of procedures and standards which can be used to evaluate the “MR Compatibility” of hand-held, non-electronic equipment used in conjunction with the Signa system.

Included are a definition of MR Compatibility, a scheme for classification of equipment, and a set of tests and standards for assessing MR Compatibility.

A Working Definition of MR Compatibility

For the purposes of this document, “MR Compatibility” shall be defined as follows:

- A device shall be considered MR Compatible if and only if:
  - It’s presence in the Signa magnet room does not pose an increased safety risk to the patient or other personnel [MR Safety]
  - It performs its intended function when used in conjunction with the Signa system in a safe and effective manner [Device Safety and Effectiveness]
  - Its use in conjunction with the Signa scanner does not adversely impact the function of the scanner [Scanner Compatibility]

A device may be MR Compatible for certain types of use but not for others. The idea of “usage classification is discussed. Note that MR Compatibility does not imply general safety. Other normal operating room safety issues (sterility, electrical isolation, etc.) must be addressed independently of MR Compatibility.

The components of the definition of MR Compatibility are discussed below.

MR Safety

The “MR Safety” part of the definition is related to whether the presence of the device in question in or near the Signa system poses an additional safety risk. The primary areas of concern are:

- Magnet forces: The device must not be attracted to the magnet with sufficient force as to be a projectile. The device must not experience sufficient torque as to be a possible source of injury.
- Heating: The device or immediately surrounding tissue must not have the potential to become hot enough to cause injury during scanning.

Device Safety and Effectiveness

“Device Safety and Effectiveness” refers to whether the introduction of the device into the Signa environment alters the way in which the device functions. In order to be MR compatible, the device must perform its intended function effectively and in a way that does not pose a safety risk while in the Signa SP scanner environment.

NOTE: GE shall not be responsible for assessing the proper function of any device. The manufacturer of the device must make arrangements to test their device in the MRI environment. Written certification that the device functions as intended in the MRI environment shall be provided before the device shall be considered MR compatible.

The following are aspects of the MRI environment which may impact device function:

- Large static magnetic field
- Rapidly changing magnetic field
- Radio frequency energy

Scanner Compatibility

Scanner compatibility refers to whether the use of the device in conjunction with the scanner adversely effects scanner performance (signal to noise ratio, artifacts, image distortion, etc.). The areas of concern are:

- Static Magnetic Field Homogeneity: The device must not cause significant changes in the main magnetic field homogeneity.
- Radio Frequency Interference: The device must not distort the transmit pattern of the RF energy used for imaging. The device must not generate significant radio frequency (RF) energy in the sensitive range of the scanner.

Classification

This document applies to hand-held, non-electronic devices. The degree of MR Compatibility required for a device is broken into four “zones” according to where the device will be used during scanning. Knowledge of the correct MR Compatibility Zone allows the appropriate MR Compatibility tests and standards for the device in question to be determined.

Testing Approach

The tests used to assess MR compatibility fall into the following areas:

- Magnet Forces and Torques
- Heating
- Magnet Field Distortion (Static)

Each area has tests and acceptance criteria appropriate to the MR Compatibility Zones.

When a new device is considered for MR Compatibility, it is first classified. Then the appropriate tests and acceptance criteria are chosen. Once the device passes the tests, and the device manufacturer has provided in writing the results of their functionality tests indicating that the device functions as intended in the MR environment, the device may be designated “MR Compatible” for the Zone tested. The tests are designed such that MR Safety is independent of the Zone tested. For example, a Zone 4 hand-held device may be safely positioned at iso-center and scanned but may cause severe image distortions and/or artifacts.

Results of MR Compatibility testing should be maintained on file at the site along with design drawings and any other documentation necessary to describe the device. Since design changes may make the device incompatible, any changes must be reviewed with and approved by the site testing personnel in order to maintain the “MR Compatibility” of the device. Some changes may necessitate retesting.

Applicable Documents

MR Compatibility Test Specifications

- Magnet Forces and Torques Test Specification
- Heating Test Specification
- Magnet Field Distortion (Static) Test Specification

Classifications

In order to manage the tremendous variety of devices and applications, the following classifications are used throughout this document.

Device Classifications

The tests specified assume the device has the following properties:

- Electrically Passive: The device contains no electric or electronic circuitry.
- Hand-Held: The device can be comfortably lifted and manipulated with one hand by a typical person. Such devices typically will weigh less than 2kg.

Usage Classifications

The degree of MR compatibility required depends on the intended use of the device. The degree of MR compatibility shall be designated Zone 1, 2, 3, or 4:

- A device which is Zone 1 MR Compatible is suitable for use in the imaging volume, potentially in contact with the patient, during scanning.
- A device which is Zone 2 MR Compatible is suitable for use in the imaging volume, potentially in contact with the patient, during scanning, provided that the device is at least 5cm away from any anatomical feature for which spatially accurate images are required.
- A device which is Zone 3 MR Compatible is suitable for use in the imaging volume, potentially in contact with the patient, when not scanning. The device should be moved outside of 1.0 m from iso-center during scanning.
- A device which is Zone 4 MR Compatible is suitable for use in the scan room during scanning when kept more than 1.0m from iso-center.

The highest Zone of MR Compatibility is Zone 1. A Zone 1 MR compatible device may be used in the imaging volume in the region of interest without degradation of image quality or spatial accuracy. Biopsy needles and endoscopes would typically be Zone 1 devices. A Zone 2 device may be used in the imaging volume but can cause spatial distortions and artifacts nearby (within 5cm). Typical Zone 2 devices would include positioners and microscopes. A Zone 3 device should be removed from the scan volume prior to scanning to avoid spatial distortion and artifacts. The majority of MR Compatible hand-held surgical instruments would be Zone 3 devices. A Zone 4 MR compatible device should not cause problems only if it is no closer than 1.0m from iso-center. Typical Zone 4 devices include furniture and carts. Note that the same type of device can be made MR Compatible to any Zone depending on the material used in fabrication. For example, a scalpel can be either Zone 1, 2, or 3. A scalpel made of a non-ferrous metal might be Zone 3 MR Compatible, while one made of ceramic could be Zone 1 MR Compatible.

Test Descriptions

This section describes in general terms the tests used to assess MR Compatibility. Please see the referenced test procedures for detailed test descriptions. The tests used to assess MR compatibility fall into the following areas:

- Magnet Forces and Torques
- Heating
- Magnet Field Distortion (Static)

Magnet Forces and Torques

The following are general descriptions of the tests used for magnet forces and torques. Please see document “MR Compatibility Tests: Magnet Forces and Torques Test Specification” for a complete description.

MFT Test 1: Screening

Part A

This test is to be performed outside of the screen room. A hand magnet is suspended on a string and the device is slowly brought into contact with the magnet. If the hand magnet is strongly attracted to the device, the test fails. See “MR Compatibility Guidelines: Magnet Forces and Torques Test Specification” for details.

Results: Pass/Fail

Part B

This test is to be performed using the Signa magnet. Only devices which have passed the screening test should be tested. The following apparatus is required: clear plastic box with locking lid, paper, marking pen.

The device is placed in a clear box on top of a sheet of paper, its outline is traced on the paper and the lid closed and locked. The device is then moved into the magnet bore and then removed from the bore. If the device moves or pivots as it moves into or out of the bore, it fails. The test is repeated with the device oriented 90 degrees from its original position.

Results: Pass/Fail

MFT Test 2: Small Object Test

This test is to be performed using the Signa magnet ramped. Only devices which have passed the screening test should be tested. The following apparatus is required: deflection meter.

The device is suspended from a string and slowly carried toward the Signa magnet until it is positioned in a known magnetic force area. The angle of deflection of the string (and thus the force on the device) is monitored.

Results: Pass/Fail

Heating

The following is a general description of the Heating test. Please see document “MR Compatibility Guidelines: Heating Test Specification" for a complete description. The tests are applicable only for devices which can physically be located inside of a 1.0m diameter sphere centered at iso-center during scanning. Other devices may be exempted.

Heating 1: Heating Test 1

This test is used for devices which may be in surface contact with the patient or operator during scanning and for devices which may be inserted into the patient during scanning. This test is to be performed using the Signa magnet ramped.

Use one of the conductive gel samples specifically designed for the heating test. Paint the exposed surfaces of the device with the temperature sensitive paint. The paint is water-based and undergoes a permanent change if its temperature exceeds a specific value. Position the device next to or in the gel as it would be positioned in the skin. Run the Heating Test PSD listed under the GE Protocols on the system. Remove the device from the scanner after the scan is complete and examine the device to determine if any surfaces exceeded the prescribed temperature. If any surfaces exceeded the appropriate temperature threshold the device fails.

Results: Pass/Fail

Magnet Field Distortion

The following are general descriptions of the Magnetic Field Distortion tests. Please see document “MR Compatibility Guidelines: Magnetic Field Distortion Test Specification” for a complete description.

MFD Test 1: Local Field Disturbance

This test is to be performed using the Signa magnet ramped. Only devices which have passed the magnet forces test should be tested. Zone 3 and Zone 4 devices do not need to be tested.

This test is designed to evaluate local field disturbances from devices that would be in the imaging volume during scanning. A copper sulfate phantom is scanned, then the device is submerged in the solution and the phantom is re-scanned. The change in field due to the device is measured and the potential impacts on signal intensity and spatial accuracy are reported.

Results: Zone 1: Pass/Fail
Zone 2: Pass/Fail

Test Procedure

The following procedure shall be used to assess whether a device is "MR Compatible".

1. Make sure that all the appropriate documentation has been provided: the documentation shall include a detailed mechanical drawing indicating the types of materials used in fabrication.
2. Determine the appropriate device and usage classifications.
3. Perform the magnetic force screening test. If the device passes, go on to step 4. If not, the device shall not be designated "MR Compatible".
4. Confirm that the manufacturer performed a test of the device functionality in the Signa system and/or provides satisfactory documentation indicating that the safe function of the device is not compromised by its introduction into the MR environment.
5. Determine the appropriate tests for the device.
6. Perform the indicated tests and record the results. If all the test results are within the acceptance criteria, the device may be considered "MR Compatible" to the lowest Zone passed.

The results of the MR Compatibility test shall be recorded on the MR Compatibility data sheet.

Please reference the indicated sections for test descriptions.

Table APX-1 Compatibility Test Selection

	Magnetic Force	Heating	Field Distortion
Zone 4	4.1.2	4.2.1	n/a
Zone 3	4.1.2	4.2.1	n/a
Zone 2	4.1.2	4.2.1	4.3.1
Zone 1	4.1.2	4.2.1	4.3.1

Table APX-2 Compatibility Test Acceptance Criteria

	Magnetic Force	**Heating**	**Field Distortion**
Zone 4	<30° deflection	<5°C	n/a
Zone 3	<30° deflection	<5°C	n/a
Zone 2	<30° deflection	<5°C	<100 counts above zero distortion (at 5cm)
Zone 1	<30° deflection	<5° C	<100 counts above zero distortion

MR Compatibility Data Sheet

Device Information

Device Name: ____________________ Model #: ____________________

Manufacturer: ____________________ Serial #: ____________________

Description: ____

____

____

Documentation Checklist:

- ❑ A set of detailed mechanical drawings indicating the type of material used (attach copy)
- ❑ Results of Manufacturer test indicating the device functions as intended in the MRI environment (attach copy)

Device Classification:

Circle One: Handheld portable stationary

Circle One: electrically active electrically passive

MR Compatibility Zone Required (circle one)

1 2 3 4

Results of Magnetic Forces Screening Test: Pass Fail

Comments (if failed): ____

____

List the required tests from Table 1 along with test results:

Test	**Results**	**Status (circle lowest Zone passed)**				
____	____	4	3	2	1	none
____	____	4	3	2	1	none
____	____	4	3	2	1	none
____	____	4	3	2	1	none
____	____	4	3	2	1	none
____	____	4	3	2	1	none
		____	____	____	____	____
	Overall Status (circle highest of above)	4	3	2	1	none

Magnetic Forces and Torques Test Specification

Scope and Summary

Introduction

This document describes the Magnetic Forces and Torques (MFT) Test Specification called out in the “MR Compatibility Test Guidelines for the Signa System.” Three tests are described:

- MFT 1: Screening
- MFT 2: Small Object Test
- MFT 3: Small Object Test

The MFT Screening Test Part A (MFT 1A) is designed to exclude devices which may be strongly attracted to the Signa magnet. The results of the MFT Screening Test Part A shall be either “Pass” or “Fail”. The MFT Screening Test Part A shall be performed prior to the introduction of any device under consideration for the MR Compatibility into the magnet room. The MFT Screening Test Part B (MFT 1A) is designed to pass devices which experience no force or torque while in the Signa SP magnet. The MFT Screening Test Part B involves moving the device into and out of the magnet and detecting any translation or rotation of the device. The results of the MFT Screening Test Part A shall be either “pass” or “fail”.

The MFT Small Object Test 2 (MFT 2) shall be used for devices which have passed the screening test (MFT 1). The test involves moving the device toward the magnet in a controlled fashion while the force on the device is monitored.

Applicable Documents

MR Compatibility Test Guidelines for the Signa System

Test Equipment

The MFT Screening Test Part A requires the use of a hand-held permanent magnet. The magnet used shall be an Edmund Scientific 25 lb. pull SN #40847 or equivalent.

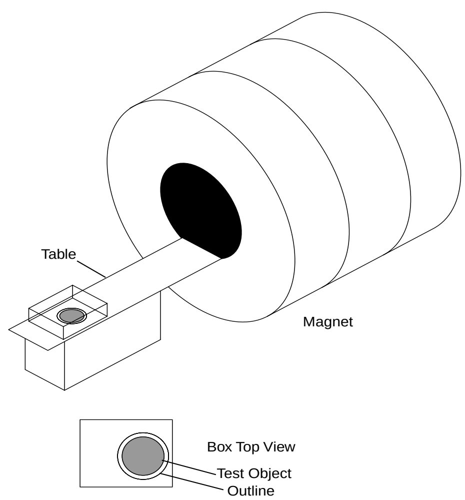
The MFT Screening Test Part B and the MFT Small Object Test 2 require the use of the Signa magnet. The following apparatus is required:

- MFT Screening Test — Part B
  - Clear Plastic box with locking lid
  - Plastic box-sized sheets of paper
  - Marking pen
- MFT Small Object — Test 2
  - Deflection meter (level - equipped protractor with a string attached)
  - Mesh bag

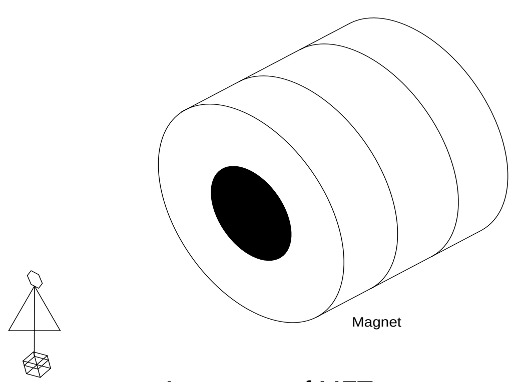
Test Procedures

Small Object Test 1: Screening Test

Part A



Apparatus of MFT Screening Test Part B



Apparatus of MFT

The MFT Screening Test Part A shall be performed outside the screen room. Suspend a hand magnet (Edmund Scientific 25 lb. pull SN#40847 or equivalent) with a string (as opposed to a metallic wire). Slowly bring the device into contact with the magnet. If the magnet moves and the string deflects from vertical before the device touches the magnet, or if the device sticks to the magnet and pulls the magnet so that the string deflects from vertical, the device fails.

Results: Pass/Fail.

Part B

The MFT Screening Test Part B is designed to detect any magnetic force or torque on a device. Only devices which have passed the Magnetic Forces and Torques Screening Test Part A should be tested.

The MFT Screening Test Part B uses the setup shown in Figure 2. While outside the procedure room, place the device to be tested into the plexiglass box on top of a piece of paper which has been taped into the bottom of the box. Draw an outline of the device on the paper to indicate its initial position. Close and secure the lid. Place the box on the outer end of the patient table and secure it to the table. Make sure that the device has not shifted. Move the table such that the box with the device is moved to magnet iso-center, then return it to the starting position. If the position of the device relative to its outline has not changed (including rotation), the device passes. Repeat the test with the device oriented 90 degrees from its original position.

Results: Pass/Fail

Small Object Test 2

The Magnetic Forces and Torques Small Object Test 2 is designed to determine the magnetic force and torque on a device. Only devices which have passed the Magnetic Forces and Torques Screening Test (MFT 1) should be tested.

The Magnetic Forces and Torques Small Object Test 2 uses the setup shown in Figure 1. While outside the procedure room, place the device to be tested into a mesh bag. Adjust the position of the device in the bag such that its long axis is parallel to the floor. Run the string attached to the mesh bag through the center hole of the deflection meter.

Hold the deflection meter level, out in front of you and pointing at the magnet as you enter the procedure room. Walk slowly toward the magnet while observing the angle of deflection. Make sure to keep the device between yourself and the magnet. If the angel of deflection exceeds 30°, stop the test and remove the device from the procedure room. Otherwise, continue moving toward the patient end of the magnet until the top center of the deflection meter touches the top of the magnet opening at the patient end. Align the deflection meter with the Z axis of the magnet. Record the maximum deflection on the data sheet. If the deflection angle exceeds 30° the device fails.

Results: Pass/Fail

Heating Test Specification

Scope and Summary

Introduction

This document describes the Heating Test Specification called out in the "MR Compatibility Test Guidelines for the Signa System."

The Heating Test is designed to detect if the device interacts with the Signa system so as to create hazardous temperatures when positioned in the patient or when in contact with the patient's or operator's skin. The maximum safe internal temperature is 41°C, which represents a 4°C rise from normal internal temperature of 37°C. The maximum skin exposure temperature allowed is also 41°C. Skin temperature can reach 37°C during MR scanning, so a temperature increase of 5°C would exceed the allowed temperature. Thus, the temperature level to be detected by the heating test is 28°C, which represents a 5°C rise above normal room temperature of 23°C.

Applicable Documents

MR Compatibility Test Guidelines for the Signa System

Test Equipment

The Signa Heating Test requires the use of a temperature sensitive marking material such as Omega OMEGASTIK Temperature Indicating Crayons or OMEGALAQ Temperature Indicating Lacquer. These materials melt at a specific temperature and maintain an altered appearance when cooled. The specific model used should melt at a temperature of 28°C, assuming a room temperature of 23°C.

The Signa Heating Test also requires the use of a tissue-simulating material. A gel phantom designed to simulate the electrical conductivity properties of tissue has been developed. The gel consists of 9.70% TX-150 (Oil Center Research, Lafayette LA), 9.06% aluminum powder (JT Baker Chemical Co., Phillipsburg, NJ), 80.97% water and 0.27% NaCl.

Test Procedure

Part 1 of the test can be performed outside the procedure room. Part 2 of the test is to be performed in the Signa magnet. Only devices which have passed the required magnet forces and torques test should be tested.

Part 1: Pre-Test Inspection

Before testing the device, inspect it for the following:

- Construction material
  - If the device is constructed entirely of a non-conductive material such as ceramic or plastic (as indicated in information supplied by manufacturer and confirmed by inspection) it may be exempted from further Heating testing.

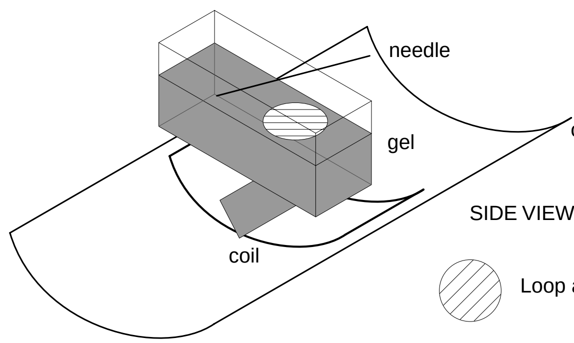
Part 2: Scanner Testing

Apply the temperature indicating material to the surfaces of the device to be tested. Lay the body-flex coil flat on the table at iso-center. Position the device in the tissue simulating gel in a manner that duplicates the relative position between the device and tissue. Place the gel/device on top of one of the sides of the body-flex coil with the long axis of the device aligned perpendicular to the magnet's Z axis. Refer to Figure 1 for recommended coil/device configurations. Scan the device with the Heating Test protocol listed under the GE protocols. The Heating Test protocol exposes the device to the maximum RF power possible on the system for a period of 15 minutes. Observe the device via the over-patient camera during the scan. If you can visually verify that the temperature sensitive material is undergoing a color change you can stop the scan before it's completion to prevent damage to the device. If no change is detectable during the scan, wait for the scan to finish, then remove the device and inspect for temperatures exceeding the melting point of the indicating material. If the indicating material melted at any point on the device, the test fails.

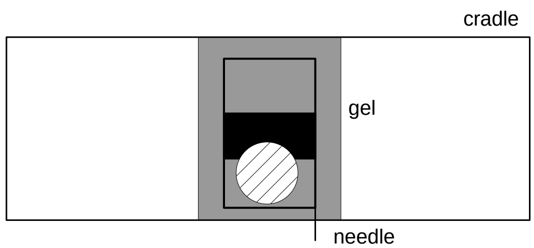
Repeat with the long axis of the device aligned parallel to the magnet's Z axis. If the indicating material melted at any point on the device, the test fails.

If the device has some loop area, repeat the test with the loop area perpendicular to the magnet's Z axis. Refer to Figure for recommended coil/device configurations. If the indicating material melted at any point on the device, the test fails.

A needle is shown in the figures for demonstration purposes. The needle axis represents the long axis on the device being tested.

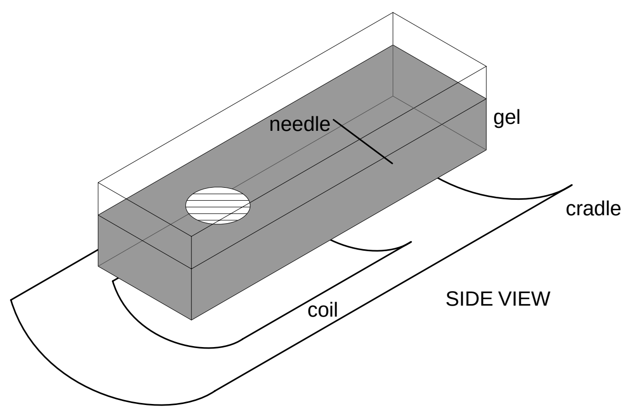


Loop area of device

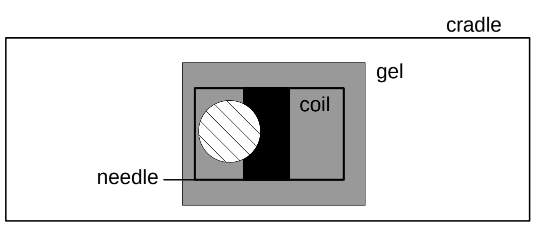


TOP VIEW

Long axis of device perpendicular to magnet axis



SIDE VIEW



TOP VIEW

Long axis of device parallel to magnet axis

Table APX-3 Data Log

Distance From Instrument	Instrument Description (MFG, SN#, ETC)						Date _______________	
	Plane	Max	Min	Max Deviation from Zero	Max	Min	Max Deviation from Zero	Pass/Fail

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Numerics

B

C

D

G

R

W

Z