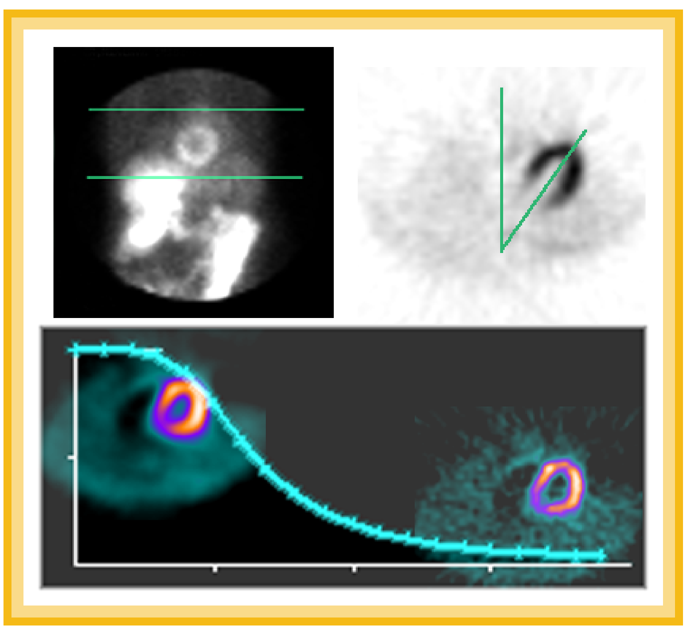
The Emory Reconstruction Toolbox™

Version 1.0

Operating Instructions



Revision 02 (April, 2008)

Operating Instructions

The Emory Reconstruction Toolbox Application

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Table of Contents

Introduction to Emory Reconstruction Toolbox

Before You Begin

This chapter contains important information you need to know before using the Emory Reconstruction Toolbox Application, including warnings, errors, and limitations, as well as information on how to use this manual.

It is assumed that you have a working knowledge of nuclear medicine and are familiar with the operation of your Computer System.

About the Emory Reconstruction Toolbox Application

The Emory Reconstruction Toolbox can be used to reconstruct, reorient and display tomographic myocardial images acquired using SPECT radiotracers such as sestamibi (with or without attenuation correction), tetrofosmin or thallium.

This software can operate on a single rest study, a single stress study, or a combination of both.

The Emory Reconstruction Toolbox has some features that operate on images automatically, with the opportunity for the user to review these steps and override them if desired. The program generates gate-summed projection images, and oblique-angle tomographic slices suitable for either visual review or quantitative analysis.

This manual describes the Emory Reconstruction Toolbox application, as it has been implemented on your Computer System.

Warnings, Errors, and Limitations of the Emory Reconstruction Toolbox Application

Warnings

Warnings display as dialog boxes on the computer monitor screen. If you receive a warning dialog box, you can continue to perform the Emory

Reconstruction Toolbox application by clicking on the OK button in the dialog box.

If you choose to continue, be aware that your results may be affected. Individual error and alert messages are explained in more detail in the procedural instructions.

Warning dialog boxes appear if any of the following situations occur:

- The rest and stress studies have a different patient ID.
- The studies were acquired in a matrix size other than 64 x 64.

About this Manual

Conventions

Throughout this manual, the Emory Reconstruction Toolbox will also be referred to as ERToolbox. the following conventions are used to distinguish elements of text:

W A R N I N G

This is an example of the way warnings will appear in the manual. Warnings are used to alert you to situations that could result in personal injury and/or serious system damage.

Caution: *This is an example of the way cautions will appear in the manual. Cautions are used to alert you to situations that could result in damage to the system hardware or software.*

Note: This is an example of the way notes will appear in the manual. Notes provide additional information about the current process or procedure, as well as parenthetic information regarding operation procedures.

Example: This is how an example appears in the manual. Examples are used to illustrate procedures or concepts.

<u>Underlined text</u> is used to introduce a numbered sequence of steps that the user is to follow.

Bold Text is used for section and sub-section headings. In addition, buttons and menu items that appear in ERToolbox are discussed using their labels--the exact text the user sees--and these are bolded within the text of this manual.

Chapter Contents

The chapters in this manual are organized as follows:

- Chapter 1, *Introduction*, provides information about the manual, as well as important information you need to know, before using the Emory Reconstruction Toolbox application.
- Chapter 2, *Using the Emory Reconstruction Toolbox Application*, describes all of the processing options and features.
- Appendix A, *References*
- Appendix B, *Recommended Protocol Parameters*

About Figures

All illustrations in this manual are representative samples only. While your results will be similar in appearance, the data presented will reflect the study you are processing.

Throughout the manual, figures are used to illustrate the appearance of review screens and user interface elements such as buttons and lists. The screens that you see in ERToolbox may have blue, gray or tan backgrounds, depending on the Windows settings of the computer on which the software is running. Consequently, the figure background color may not match your particular machine.

Using The Emory Reconstruction Toolbox

This document describes the Emory Reconstruction Toolbox application (ERToolbox). In this document you will learn about:

- Selecting the appropriate patient, studies and datasets.
- How to reconstruct and re-orient images.
- How to apply various corrections to images.
- How to review reconstructed studies.

Acquisition Protocols

The ERToolbox application requires that the acquisition be performed using a 64x64 image matrix. Appendix B of the ERToolbox user manual provides recommended acquisition and reconstruction parameters for various clinical protocols, such as Dual-Isotope, Tl-201, Tc-99m Sestamibi and Tc-99m Tetrofosmin.

Caution: *This application is more dependent on technical quality control than a planar imaging protocol. A major source of false positive studies is the failure to acquire and process these studies accurately. It is important that the user ensure complete quality control, as described in the manuals that accompanied your nuclear medicine camera system.*

Procedural Overview

The steps necessary to reconstruct studies and display results are listed briefly here. Detailed instructions follow in the next section.

Quick Steps

1. Select data to be reconstructed, and make sure it is identified correctly using the Study Verification window.
2. Select the protocol to be used for reconstruction. The protocol will specify the type of reconstruction, the filters to be applied, and the corrections to be applied.
3. Verify the automatic reconstruction. Change the reconstruction limits on the transaxial image if necessary.
4. Verify the automatic re-orientation. Change the angles, filters or image corrections as necessary.
5. Review the final set of images for accuracy.
6. Save images, or use the **ECToolbox** button to transfer them to the Emory Cardiac Toolbox application, for quantitative processing.

Identifying Datasets for Processing

This application requires either one or two datasets consisting of tomographic projections. In the remainder of this manual, we will refer to these as “Study 1” and “Study 2”. In many cases, the two datasets will be the rest and stress portions of a patient study. Study 1, Study 2 or both can be ECG-gated.

Study Verification Window

When input data is selected, the *Study Verification* window is displayed. ERTb first checks to see if all the expected information is stored with the image. If not, the program will present one or more dialog boxes to inform you of what’s missing, and it will make assumptions about how the data should be processed. For example, the program only handles data that has been acquired using parallel hole collimation. If no collimation information is found in the image, parallel will be assumed, and a message will be displayed, as shown in Figure 2-1. After you dismiss this dialog, you can begin working with the Study Verify window.

Figure 2-1. A message that appears if certain information is missing. Dismiss this dialog to continue processing.

The various parts of this large dialog window are shown in Figure 2-2 through Figure 2-4.

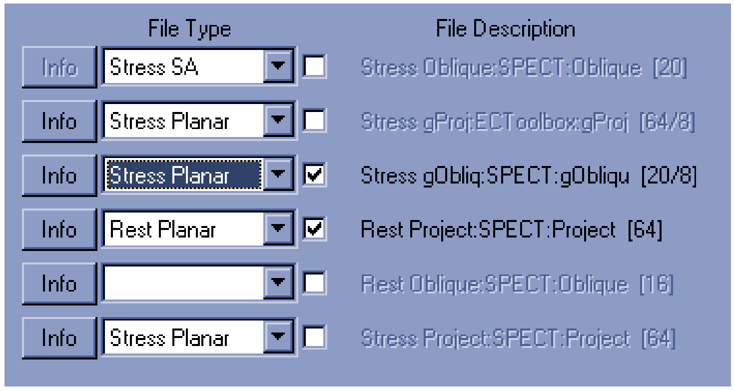

Figure 2-2. The left part of the Study Verification Dialog Box. Note that, under "File Description", the number of images in the file is listed in brackets. This information can help distinguish one file from another in case the filenames are ambiguous.

The Study Verification dialog shows the list of user-selected files. Those that have a File Type box that is filled in (with "Stress Planar" for example) are files which the program was able to identify as valid inputs. The user can examine this list and change the file type by selecting another entry from the drop-down list. To the right of the drop-down list is a checkbox. If this box is checked, the program has determined that the file is to be used as the indicated type. If more than one file of the same type is present, the first one identified will have its box checked.

Suppose, for example, that the software identifies a particular file as Stress Planar. If the user is certain that this file is actually the Rest Planar, then "Rest Planar" can be selected from the drop-down list, and this will cause the program to use this file as the Rest Planar. Then another file would have to be identified as the Stress Planar. See Figure 2-3.

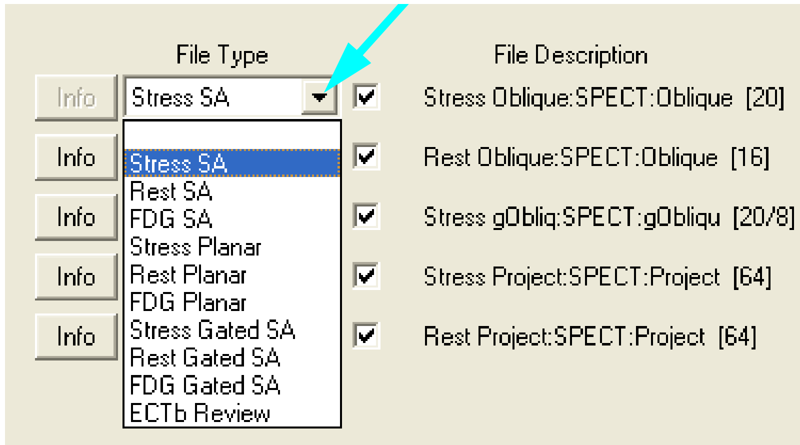

Figure 2-3. A drop-down list of all file types that ERToolbox understands is always available . In this example, the user has clicked the “down arrow” symbol for the Stress Planar file (indicated by the blue arrow).

In Figure 2-4, the lower portion of the Study Verification dialog is shown. In this section labeled “Info”, some of the information that is known for the currently selected file is summarized. To know which file is selected, look at the upper **File Type** area of the dialog. The file whose **Info** button is grayed out (cannot be clicked) is the currently selected file. To select a different file and see its information, click its **Info** button.

The selected images should be 64x64 pixel images.

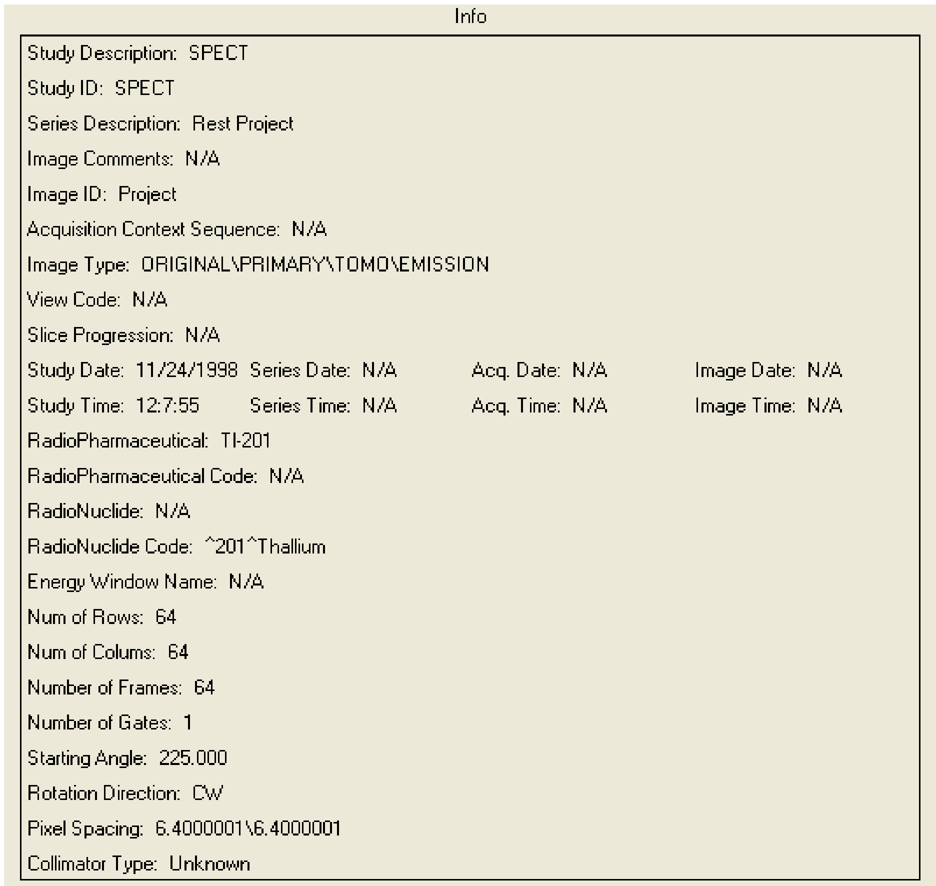

Figure 2-4. The lower portion of the Study Verification dialog.

Caution: *It is extremely important that the user verify the accuracy of the identified images, prior to proceeding with the application.*

Once the images are properly identified, continue by clicking the **Proceed** button, which will begin reconstruction.

Buttons and Controls in Emory Reconstruction Toolbox

An example of the complete ERTb display is shown in Figure 2-5.

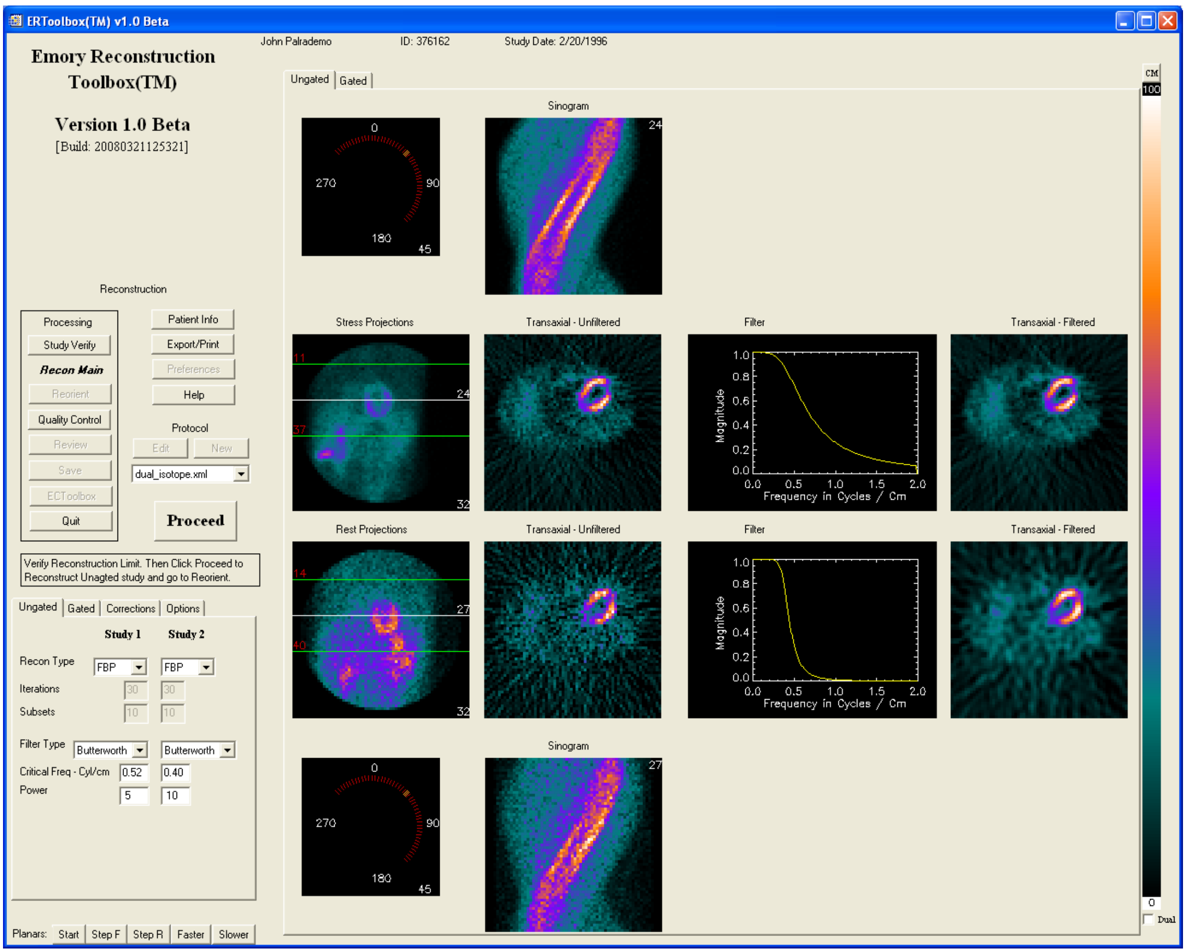

Figure 2-5. The ERTb interface. Here rest and stress images are being reconstructed. Details will be discussed in the following sections of the manual.

ERToolbox has a set of buttons and controls that are always displayed on the left side of the screen. Some of these controls will be disabled at times, depending on where you are in the reconstruction process. The interface can be broken down into several sets of controls, as explained below.

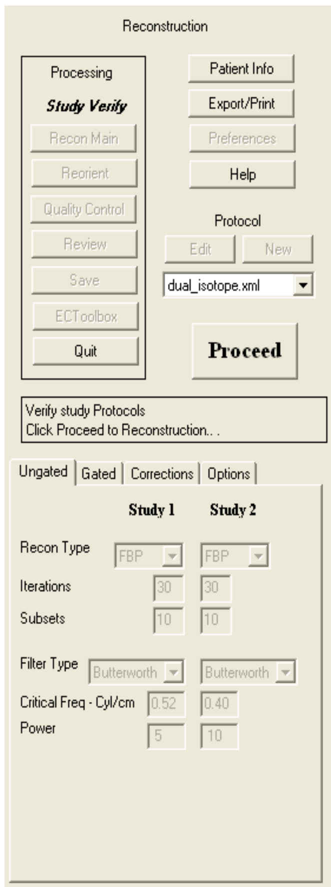

Figure 2-6. The main user interface controls for ERToolbox, which appear at the left side of the screen.

The top half of the user interface consists of buttons for controlling the flow of image processing steps, general features of the ERToolbox program, and access to stored protocols. Below these buttons are three tabs which contain buttons for setting options for reconstruction of gated and ungated images. At the bottom of the user interface are buttons for controlling the dynamic cine of planar projections.

In the ERToolbox program, a button has three possible states, indicating whether the option it represents can be selected. This is illustrated in Figure 2-7. The states are:

- **Available**. The button label is in black, indicating that it can be selected by clicking with the mouse cursor.
- **Unavailable**. The button label is shown in a lighter version of the default color, indicating that the function cannot currently be selected. In this state, the label text is often gray, so this is sometimes referred to as the button being “grayed out”.
- **Selected**. The button label is shown as available, and the label is displayed in italics.

Figure 2-7. Part of the ERTb Button set, showing different states of the **Recon Main** button: Unavailable for selection (left), Available (center) and Currently Selected (right). Mouse-clicking a currently selected button has no effect.

Processing Sequence Buttons

Notice that the buttons on the left side of the screen are arranged in two columns. The left column’s buttons are are enclosed by a border, and the column is labeled **Processing** (Figure 2-8). This set of buttons, from top to bottom, reflects the sequence of steps that are taken during processing. The buttons take you to various screens, and you can switch from one screen to another as necessary to verify or change an earlier step. The function of each button is discussed below.

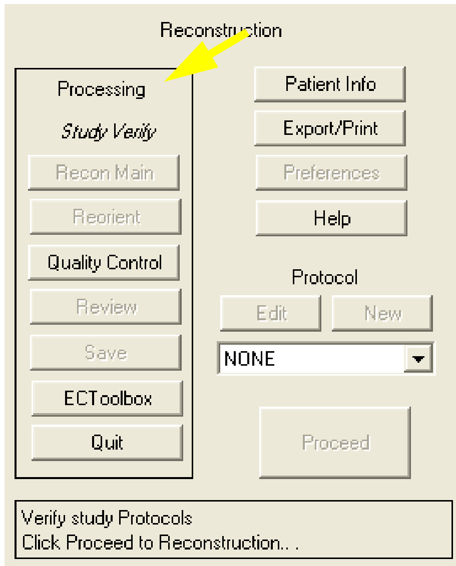

Figure 2-8. The **Processing** sequence buttons, indicated by the arrow, access the major steps in reconstruction and reorientation. The order of buttons from top to bottom represents the order in which these steps are usually executed. Quality control could be checked at any time after the Recon Main step.

Study Verify: Displays the Study Verification screen, for review of the image data that was originally selected.

Recon Main: Displays the main reconstruction screen, which shows projection images, sinogram, the current filter, and raw and filtered transaxial images.

Reorient: Displays the reorientation screen, which shows transaxial images, oblique angle slices and the planes used to generate them.

Quality Control: Displays a screen of images and calculations for assessing the overall quality of the current study.

Review: Displays a screen on which all of the reconstructed and reoriented images can be reviewed at once.

Save: Saves a review file, after the study has been processed.

ECToolbox: starts the Emory Cardiac Toolbox analysis program, using the current set of image data.

Quit: Exits the ERToolbox program.

General Control Buttons

The second column of buttons includes general program options, as shown in Figure 2-9.

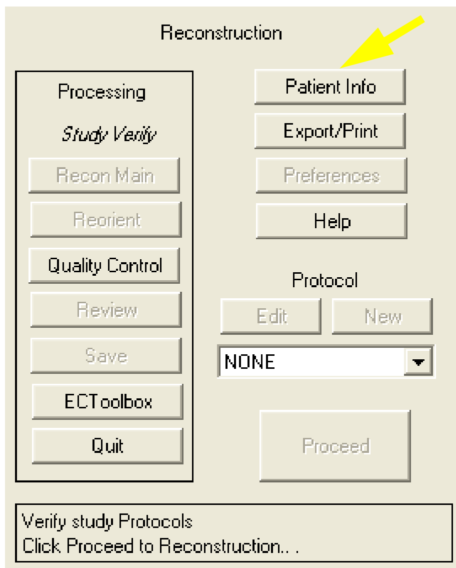

Figure 2-9. Buttons in the column indicated by the arrow control general options such as printing and program preferences.

Patient Info: Displays a summary of information about the current patient.

Export/Print: Allows the current image display to be printed.

Preferences: Allows program preferences to be inspected or changed.

Help: Displays the user manual.

Protocol Controls

Details of how a study is filtered and reconstructed are stored in protocol files. To choose which protocol is currently selected, use the controls highlighted in Figure 2-10.

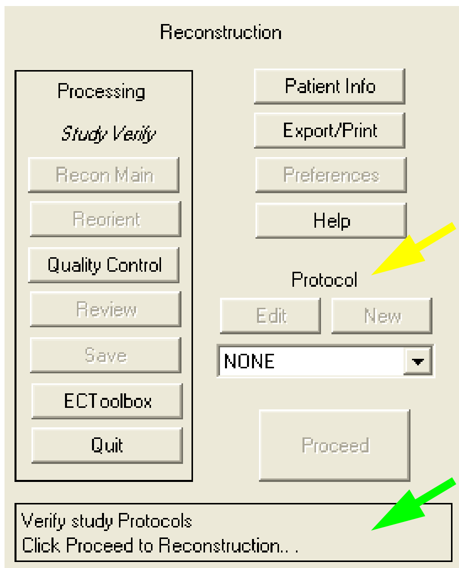

Figure 2-10. **Protocol** buttons are indicated by the yellow arrow. The droplist selects from the available list of protocols which control reconstruction details. The message area (green arrow) shows the status of the current image display, or the next step the user is expected to perform.

The protocol controls are explained in detail in section “Using Protocols in ERToolbox” on page 40, but briefly they are:

Edit: Allows the current protocol to be edited.

New: Begins the definition of a new user-defined protocol.

Protocol selection droplist: Displays a list of all of the available reconstruction protocols.

Below the Protocol controls is the large **Proceed** button. Selecting one of the Processing buttons, such as Recon Main, displays the screen associated with that function. For most screens, various parameters must be set on that screen in order to proceed with the function. Once this is done, the **Proceed** button can be used to processing data for that screen and then advance to the next step.

Below these buttons is a box which functions as a message area. Here, text is displayed that explains the current screen display, or supplies a hint for the next action the user is expected to perform.

Option Tabs

Just below the permanent button set are four tabs (Figure 2-11). The **Ungated** and **Gated** tabs contain additional controls for setting parameters specific to reconstruction of ungated and gated studies, respectively. The **Corrections** tab accesses various operations to correct problems with the images, and the **Options** tab displays details about the currently selected images.

It is important to understand the naming conventions ERToolbox uses to keep track of image data. “Stress” and “Rest” are labels that appear on the image display part of the screen, to designate images on the top (stress) and bottom (rest) of the display. These are related image sets, as defined by the protocol that was selected, so they are handled in the same ERToolbox session so that their reconstruction settings and reorientation planes can be compared.

Either stress, rest, or both can include a gated component. If gated projections are selected when ERToolbox is started, these are first summed to form an image set which the program will subsequently refer to as the “Ungated” data.

Often we want to treat the gated and ungated (summed) components of a study differently. The gated projections contain only a fraction of the counts of the summed projections, so they are typically filtered more strongly. Accordingly, ERToolbox has **Ungated** and **Gated** tabs so that filters and other processing parameters can be set independently for gated and ungated images.

Buttons and other controls contained on both the Ungated and Gated tabs are listed below.

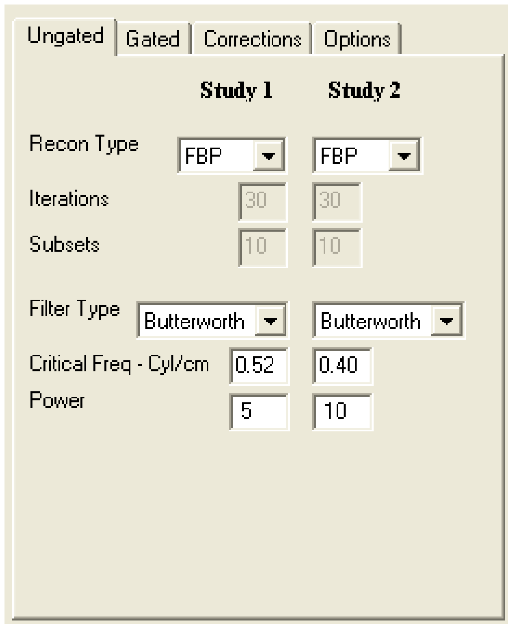

Figure 2-11. The tab area, just below the permanent buttons.

Recon Type: This droplist determines the reconstruction method, which can be FBP (Filtered Back-Projection), MLEM (Maximum Likelihood Estimation Maximization), or OSEM (Ordered-Subsets Estimation Maximization).

Iterations: MLEM and OSEM are iterative reconstruction methods. This box allows number of iterations to be set.

Subsets: This box allows the number of subsets to be set, and is pertinent only for the OSEM reconstruction method.

Filter settings for study 1:

- Filter Type: Butterworth is currently the only option.
- Critical Frequency: This parameter applies to the Butterworth filter.
- Power: This parameter applies to the Butterworth filter.

The same filter settings are displayed for study 2, and these can be set independently from study 1. The protocol you selected will set the filters automatically, but you can change them if necessary.

The **Corrections** tab includes controls which reference image corrections which can be applied. These corrections will be discussed in more detail in a later section of the manual ("Applying Image Corrections" on page 41), but briefly they are:

- Motion Correction
- Attenuation Correction
- Scatter Correction
- Resolution Compensation
- Deconvolution of Septal Penetration (DSP).

Details relating to the acquisition mode of the selected images are displayed on the **Options** tab, shown in Figure 2-12.

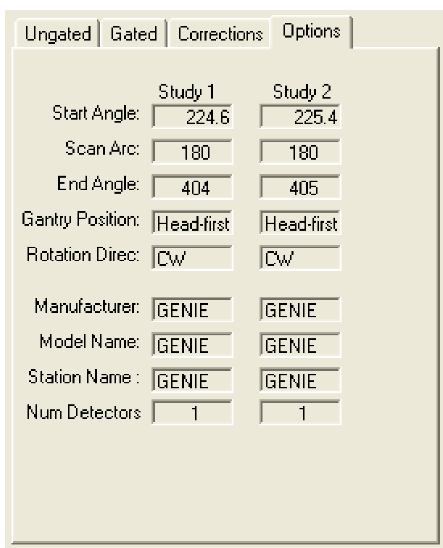

Figure 2-12. The **Options** tab.

Below the tabs are buttons used to control playback a dynamic cine of the projection images. See Figure 2-13. The buttons are:

- **Stop/Start**: stop the playback, or re-start the playback if it has been stopped.
- **Step F**: step one frame forward in the images.
- **Step R**: step one frame in reverse in the images.
- **Faster**: increase the rotation speed of the images.
- **Slower**: decrease the rotation speed of the images.

Figure 2-13. Buttons for controlling the dynamic cine of planar images.

Image Display in Emory Reconstruction Toolbox

The figure below presents the image display during the reconstruction step in ERToolbox.

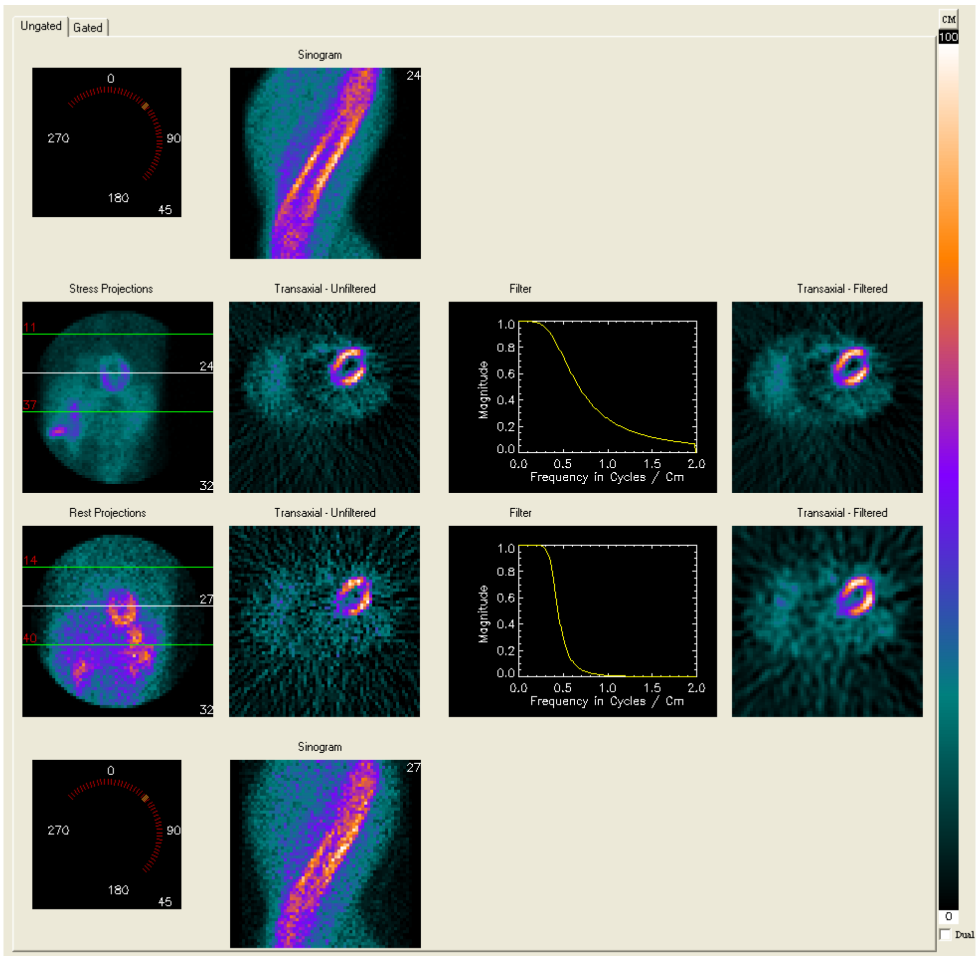

Figure 2-14. Layout of the ERToolbox reconstruction display, including a stress study (top half) and a rest study (bottom half). The arrow indicates image tabs.

The Ungated Tab

The ungated image tab is displayed in Figure 2-14. To view the gated images for the current patient study, select the **Gated** tab. The gated images will then be displayed in the same layout as the ungated images.

Notice from Figure 2-14 that the top half of the screen displays images from Study 1, which is typically the stress portion, and the bottom half displays images from Study 2, typically the rest portion. Each Study's raw and reconstructed images are displayed.

To the right of the images, on each tab, is a color bar, indicating the range of colors or gray levels used in the images. There are several ways to adjust the image display colors and intensity. These are listed below, and shown in .

- To change the window intensity, drag the top of the bar downward.
- To change color tables, click the **CM** (for "Color Maps") box at the top of the color bar. A list of available color tables will appear, and you can make a selection by highlighting the desired table with the mouse cursor.
- To enable dual color bars, for setting intensity independently for stress and rest images, click the **Dual** checkbox at the bottom of the color bar. Click the **Dual** box again to reset the window to a single

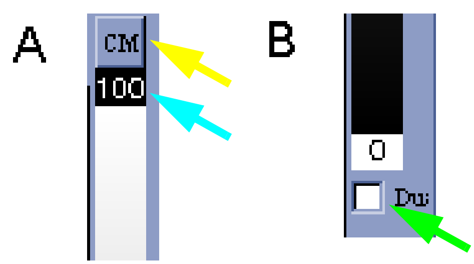

Figure 2-15. Controls on the colorbar, for changing mage color or brightness. The

Figure 2-16. The top of the bar (A) has a button for changing color tables (yellow arrow), and a button which indicates the current value of the top of the intensity range (blue arrow). At the bottom of the colorbar (B), there is a checkbox for setting or un-setting dual-level intensity control (green arrow).

Raw Data Display

Raw image display for Ungated data is highlighted in Figure 2-17

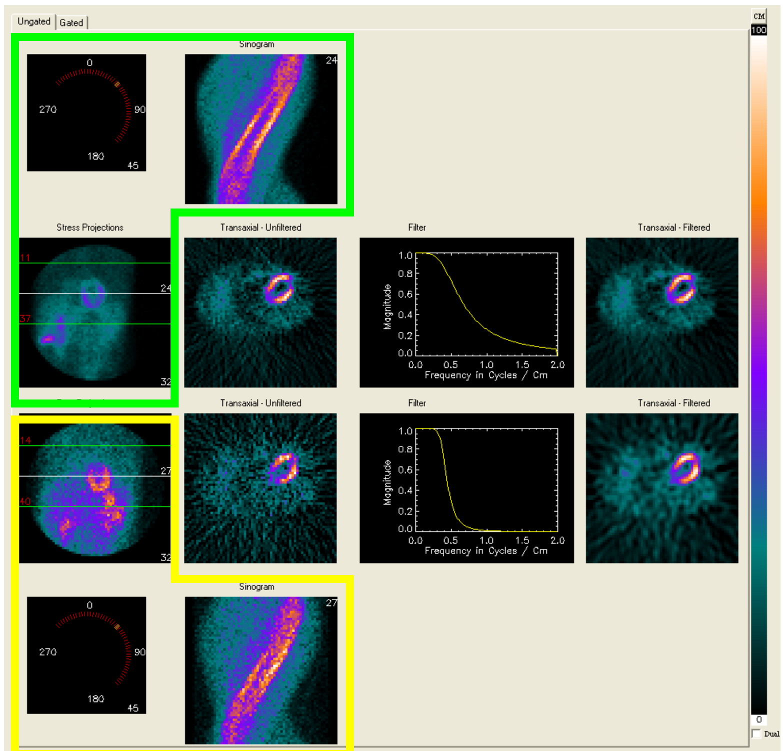

Figure 2-17. The main reconstruction screen. For the purpose of illustration, this figure highlights in green the area devoted to display of raw data for study 1. Study 2 has a similar area devoted to raw data, outlined in yellow.

The raw data display includes the following items:

- A graphic which indicates the arc used for acquisition.
- A dynamic cine of the planar projection images.
- A sinogram of the raw data.

The pointer on the arc will move as the planar cine is advanced, to visually indicate the camera position used for each projection. The zero, 90, 180 and 270-degree points are labelled, and the number in the lower right indicates the current position of the pointer, in degrees.

The projection images are displayed with automatically determined upper and lower limit lines (in green) for the heart region. You can move these by dragging them with the mouse. On the left side of each line, the pixel row number is indicated. Between the limit lines is a white line, which indicates the position at which a representative transaxial slice is taken. The row number is indicated on the right side of this line, which is the pixel row from which the sinogram is created. Dragging this line with the mouse will change the transaxial image as well as the sinogram display. To the bottom right of the planar image is a number indicating which projection is displayed.

Note: you can also right-click within the image to place the white reference slice line in another position. If you place it outside the green lines, you cannot drag it back between the lines--you must right click between the green lines, which will re-position the reference line.

The sinogram is generated automatically, and consists of pixels from the row in each projection that corresponds to the location of the reference line on the projection images. The sinogram consists of rows from each projection, and is useful for assessing lateral motion, overall study counts and count variation between projections.

Transaxial Display

The next section of the display, highlighted in Figure 2-18, shows the reconstructed transaxial image, unfiltered and filtered, and kernel for the filter that is being applied. This display enables you to see how much effect the filter has on the images.

To change the prefilter settings, or the type of filter, use the controls on the **Ungated** tab, to the left of the image display.

Note that the transaxial slice that is displayed corresponds to the location of the reference line on the planar projection image.

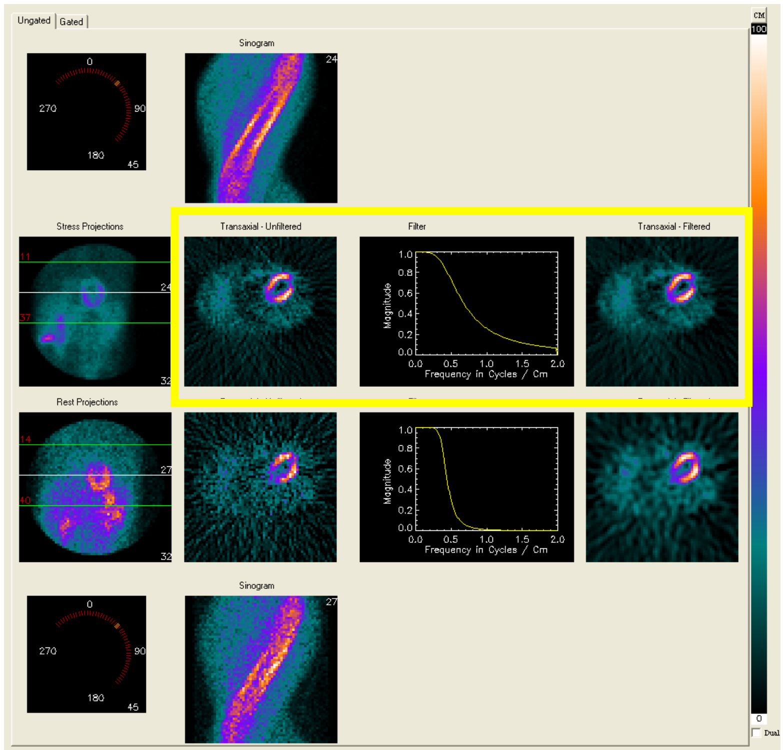

Figure 2-18. The transaxial display and related filter, highlighted in yellow.

If the patient study being processed includes resting images, these are displayed on the bottom half of the reconstruction screen. The organization of the rest display is the same as that of the stress display.

The Gated Tab

By default, the ungated tab is shown during image reconstruction, because this is where image settings, such as transaxial limits, are made. By selecting the second tab, the gated images can be reviewed with their settings. An example is shown in Figure 2-19.

The layout of images on the Gated tab is similar to the Ungated tab. If there is gated data for both stress and rest, both will be shown. On the Gated tab however, the transaxial limits cannot be moved.

Note: the filters for gated reconstruction are set independently from those for ungated reconstruction. When the Gated image tab is selected, the Gated control tab on the left side of the screen is also automatically selected. When the Ungated image tab is selected, the Ungated control tab is automatically selected.

One additional control is present on the Gated tab. This is a droplist for selecting which gate is displayed.

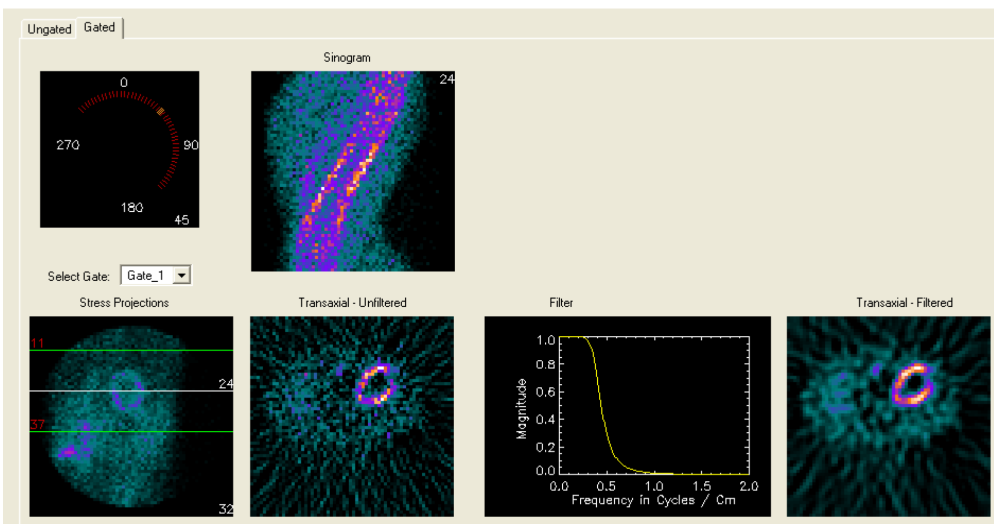

Figure 2-19. Images displayed on the Gated tab. This display is similar to the ungated display, except for the droplist for selecting which gate is displayed.

Reconstructing Images

The steps in reconstructing a study with ERTb are as follows:

1. Use **Study Verify** to make sure that you have selected all the image files you need, and that the program understands what type of image each file represents.
2. The reconstruction protocol may be correctly identified automatically by the program. The protocol name will appear in the dropdown list under the **Protocol** heading. To change to a different protocol, select one from the dropdown list.

Note: You can select any protocol from the list and review its settings before proceeding with reconstruction. Once a protocol is selected, the filters and reconstruction method specified by that protocol will be displayed in the boxes on the **Ungated** and **Gated** tabs. No reconstruction will be performed until you click the Proceed button.

3. The main reconstruction screen will be displayed (see the example of Figure 2-14). An algorithm in the program identifies the region of the heart and places lines on the projection image to indicate the superior and inferior limits of reconstruction. Only the slices between these lines (including those under the lines) will be included in the reconstructed volume. You should verify that the limits include the entire left ventricle, while not including too much of the adjacent area. You should review the limits on all of the projections by viewing the images in cine mode.
4. Click the **Proceed** button to have the program perform the reconstruction.
5. In nearly all cases, the filter settings contained in the selected protocol will produce images with the appropriate texture. If the filter needs to be adjusted, you can do so, and then repeat the reconstruction step.

Re-Orienting Images

Following reconstruction, a new image screen is displayed for image re-orientation (shown in Figure 2-20). Filter parameters are displayed on the right side of the screen. This step produces the oblique angle images which are used for both visual review of myocardial perfusion and quantitative analysis: Vertical Long Axis, Horizontal Long Axis and Short Axis.

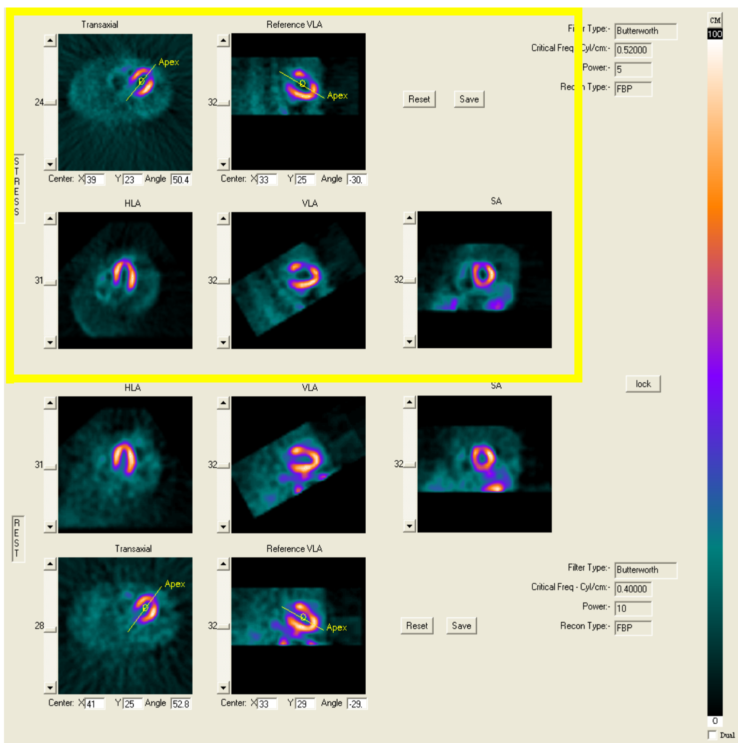

Figure 2-20. The Re-orientation screen in ERTb. The area containing the images of Study 1 (stress) is highlighted in yellow. Remaining images are from Study 2.

Manual Re-Orientation

The steps in re-orienting a study with ERTb are as follows:

1. Review the automatically determined re-orientation angles on the transaxial image. This line represents the plane along which counts are extracted to create the vertical long axis images. The line can be re-drawn by clicking on the center of the left ventricle with the left mouse button held down, and dragging outward toward the apex (or the base, if desired). The current line will disappear, and a new line will be drawn outward in both directions as you move the mouse. When you release the mouse button, the line will be fixed in that position. To re-draw, click the center and start over. There are several features of this method which you should keep in mind.

- To adjust the line position of angle, you must re-draw it, starting at the ventricular center. Once you release the mouse button, the line cannot be adjusted by dragging.
- As you draw the line, the image in the Rotated Transaxial position will change. This image shows the transaxial slice rotated according to the angle of the line you are drawing. This is a quality control feature for placement of the line: if the Rotated Transaxial appears vertical, then the line is probably correctly placed. See Figure 2-21.
- The center position and line angle values are displayed in boxes below the images where the lines are displayed.

2. Review the re-orientation angle displayed on the vertical long axis image. This line represents the plane along which counts are extracted to create the horizontal long axis images. Short axis images are extracted along a plane perpendicular to this line. The line can be re-drawn using the same method as in Step 1 above.

Limiting the Number of Slices

For either re-orientation line you draw manually, the length of the line determines the number of the slices which will be extracted in that direction. Be sure the line is long enough to extend through the entire length of the left ventricle, so there will be sufficient slices for visual interpretation or quantitative analysis.

Note: The re-orientation line defined on the Reference VLA image determines how the horizontal long axis slice are extracted. Short axis slices are also extracted, using a plane perpendicular to the line that is displayed. This perpendicular line is not displayed, nor can it be adjusted.

The “width” of short axis slices is limited only by the reconstructed volume, which is determined when the transaxial limits are set. This may be different from reconstruction software you have used in the past, in which both of these planes would be explicitly defined and their limits set.

Using the slider bars to the left of each image, you can change the slice that is displayed. The line is normally drawn on a slice through the mid-ventricle, but in the case of severe perfusion defect, several slices may need to be reviewed in order to determine the best angle. For Study 1 and for Study 2, there are **Reset** buttons. Clicking one of these buttons will reset all angles for that study.

In the middle of the right side of this display is the **Lock** button. Clicking this button causes changes made in Study 1 are also applied to Study 2. The button label then changes to Unlock. Clicking the button again causes the reorientation angles to be drawn independently.

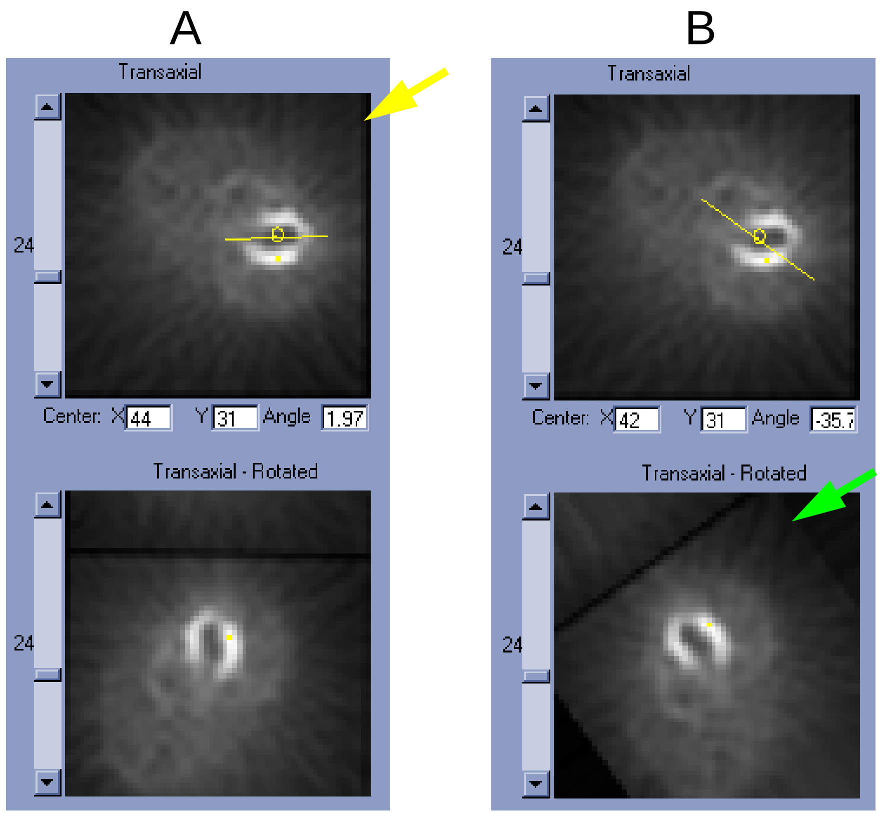

Figure 2-21. Transaxial images on the re-orientation screen, with the angle for determining where the vertical long axis images should be extracted. In version A, a line has been drawn on the Transaxial image (yellow arrow). In version B, a new line has been drawn at a different angle, causing the Rotated Transaxial image to change its angle (green arrow), by the same amount as the angle between the line you drew and an imaginary horizontal line across the image.

Using Protocols in ERToolbox

Using Pre-defined protocols

ERToolbox handles many details of reconstruction, filtering and other aspects of data handling for various SPECT imaging protocols. These details are collected and stored in files on the computer's hard drive. When the user chooses the protocol file that is appropriate for a given study, the filters, reconstruction type and other settings in the program are changed to reflect that protocol. In addition, you can create a new protocol file.

The buttons used to control protocol selection are:

Edit: Allows the current protocol to be edited. If this is one of the default protocols, then you must save the modified protocol using a different name. If a user-defined protocol is being edited, it can simply be saved after the necessary changes have been made

New: This button begins the definition of a new user-defined protocol.

Protocol selection droplist: When selected, this control displays a list of all of the defined reconstruction protocols. Any protocol can be selected from the list, and the settings it contains will be used to reconstruct the current study.

To select a protocol file, use the droplist, as shown Figure 2-22.

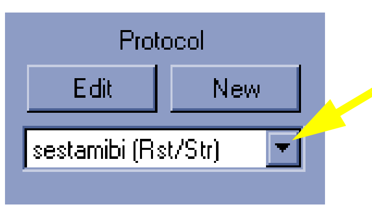

Figure 2-22. Controls used to display the list of available processing protocols and select a protocol (arrow), edit an existing user protocol, or create a new protocol.

Applying Image Corrections

There are several types of corrections that can be applied to your image data during reconstruction. Each correction has settings that determine how it is to be applied, and these settings are accessed through the buttons on the lower left of the main display, on the tab labeled **Corrections**. shows the location of the Corrections buttons.

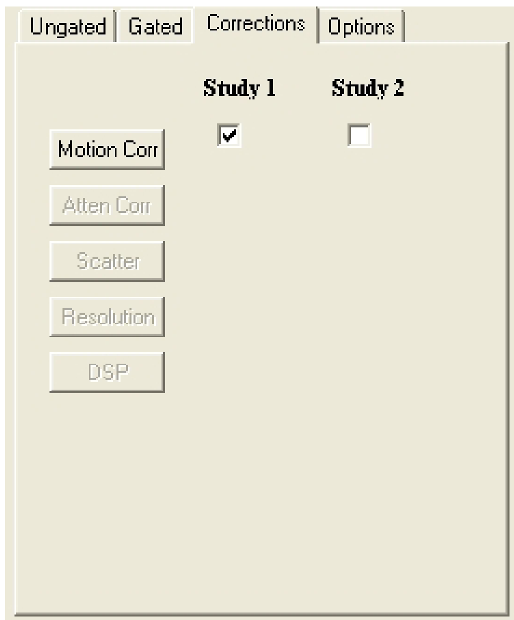

Figure 2-23. Buttons to control the various image corrections. In this example, the stress study has been selected for motion correction.

When clicked, each button displays a user interface in the image display area. Here you will see images, buttons and other controls for turning the correction on or off, and for changing how the correction is applied.

Note: For each correction, the interface allows you to control how the correction is applied to Study 1 and, independently, how it is applied to

Study 2. For the sake of simplicity, only the controls for Study 1 are shown in the figures of this section. The controls for Study 2 are exactly the same.

Motion Correction

The **Motion Corr** button on the lower left of the main ERTb screen is used to change settings that relate to motion correction. Patient motion that occurs during image acquisition can be monitored and corrected. The Screen display for motion correction is shown in Figure 2-24.

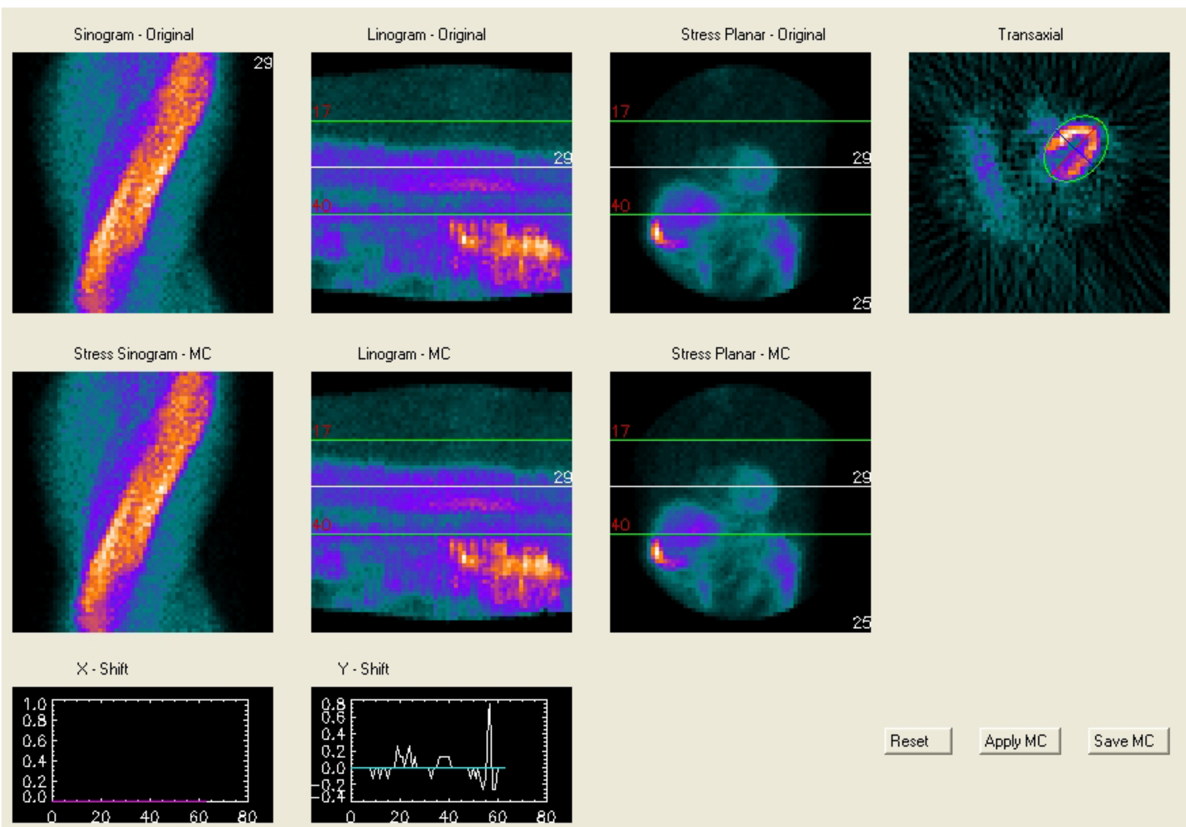

Figure 2-24. The appearance of the screen when motion correction is active. You can accept the correction and reconstruct the corrected planar projections, or revert to the original, uncorrected projections.

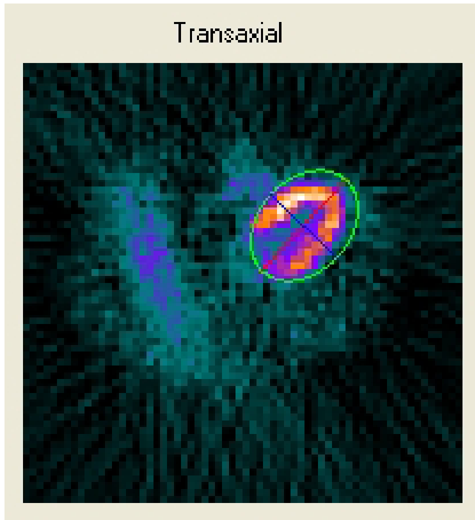

Figure 2-25. Isolation of the left ventricle for motion correction.

The user initiates motion correction by selecting the appropriate checkbox to work with either study 1 or study 2, on the **Corrections** tab, and then clicking the **Motion Corr** button, also on the **Corrections** tab. The motion correction screen will appear, including atransaxial slice which shows how the left ventricle has been identified by the program. As seen in Figure 2-25, an ellipse appears around the ventricle, with its major axis shown in red and its minor axis shown in blue. The correction software must have an accurate delineation of the ventricle in order to work properly, so if the ellipse is not positioned properly, it can be adjusted. To re-draw the ellipse, click the Reset button, and position the cursor in the middle of the ventricle, click and hold the left mouse, and drag toward the apex. This draws the major axis. Release the mouse button. When you click the left mouse again, you can drag to adjust the minor axis (width) of the ellipse.

There are three buttons on the lower right of this screen:

- **Reset** discards the current correction and allows the ellipse to be re-drawn.

- **Apply MC** uses the current ellipse and runs the motion correction software.
- **Save MC** signals the program to keep the motion-corrected planar projections and use them for reconstruction and re-orientation.

There are several parts of the display which can help identify motion that is present in the images, and summarize how much shift correction has been applied. These include the following images, each of which has an “Original” and a “MC” (for Motion Corrected) version:

- **Stress Planar**. The original planar projections are shown, with the reconstruction limits assigned on the **Recon Main** screen shown in green. Viewing the planar images in rotating cine mode is probably the best way to assess motion. Use the Cine controls on the bottom left of the screen to control the display. (These buttons are explained in).
- **Sinogram**. This image is composed of pixel rows from each projection image, stacked vertically, with the first projection at the top. The row used to extract pixels for the sinogram is indicated by the white line on the planar projections. The sinogram can show count variation between projections, and lateral motion.
- **Linogram**. This image is composed of pixel columns from each projection image, lined up horizontally, with the first projection at the left. The column used to extract pixels is determined by the ventricular center shown on the displayed ellipse, and varies by projection number. The linogram can show vertical motion in the image frame, and is a good way to visually assess the difference between uncorrected and motion-corrected images.

The amount of shift that has been applied to the projection images is indicated visually by two curve plots.

- **X-Shift** indicates the lateral shifts for each frame. If there is no lateral shift, the plot in purple will be a straight line through zero on the y axis.
- **Y-Shift**. indicates the vertical shifts for each frame. If there is no vertical shift, the plot in blue will be a straight line through zero on the y axis.

If the motion in the images has been corrected, select the Save MC button to proceed with reconstruction using the corrected images. If the correction is unsatisfactory, either re-position the ellipse or revert to the original uncorrected images. If the study is compromised by motion, the images may have to be re-acquired.

Attenuation Correction

The **Atten Corr** button on the lower left of the main ERTb screen is used to change settings that relate to attenuation correction. When selected, this button creates a display on the right side of the screen, as shown in Figure 2-26.

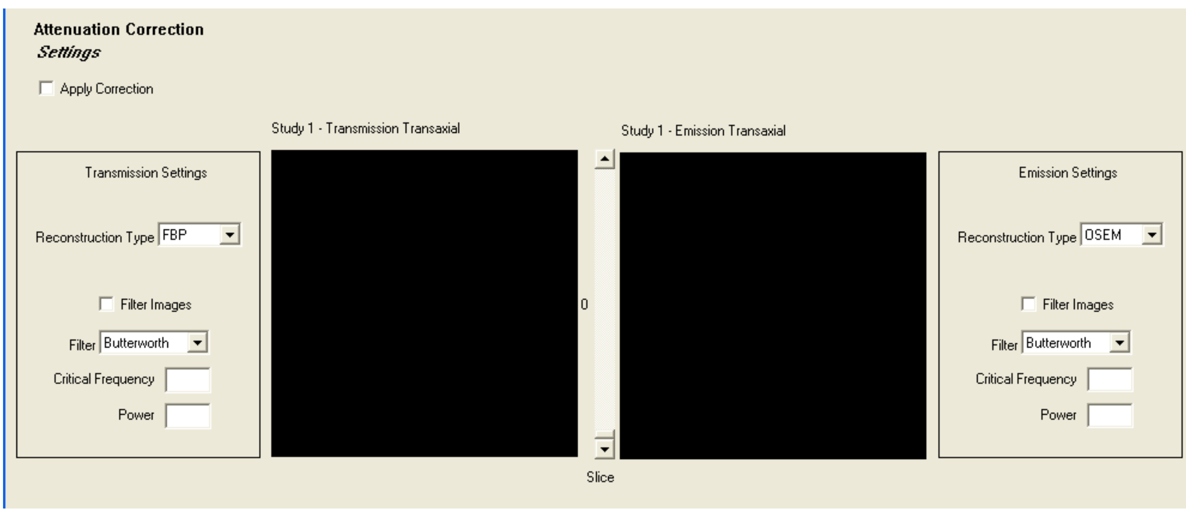

Figure 2-26. The interface for setting up attenuation correction for Study 1. There is a similar set of images and controls for Study 2.

The attenuation correction QC screen includes a checkbox in the upper left corner. If checked, this indicates that attenuation correction will be applied to the study. The transmission transaxial images are displayed, side-by-side with the emission trnasaxial images. A slider bar between the image sets will navigate through both sets of slices, which are synchronized.

Scatter Correction

The **Scatter** button on the lower left of the main ERTb screen is used to change settings that relate to scatter correction. When selected, this button creates a display on the right side of the screen, as shown in Figure 2-27.

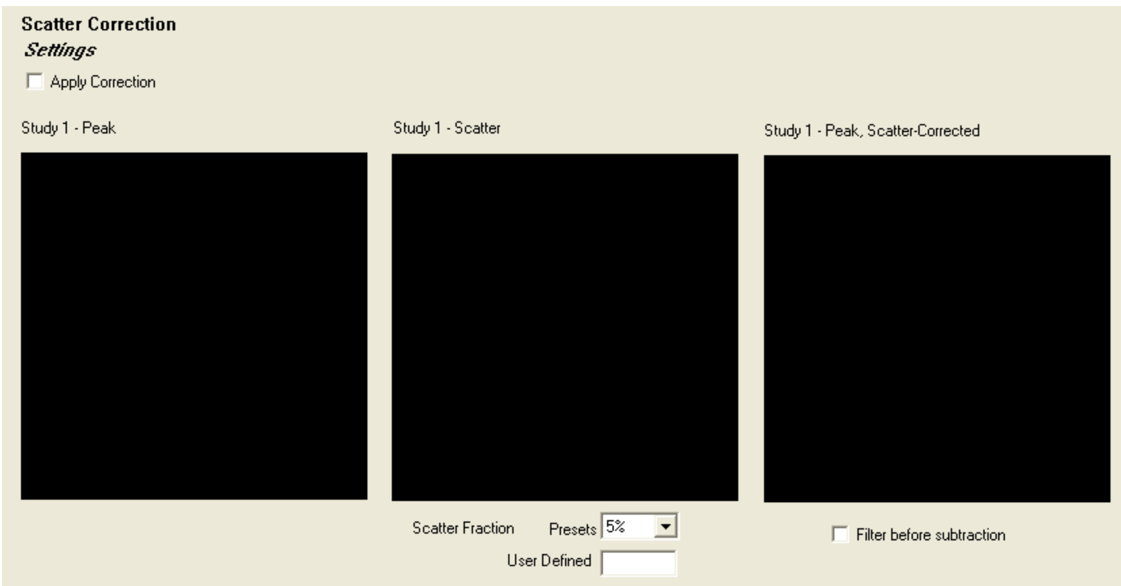

Figure 2-27. The interface for setting up scatter correction for Study 1. There is a similar set of images and controls for Study 2.

The scatter correction QC screen includes a checkbox in the upper left corner. If checked, this indicates that scatter correction will be applied to the study.

Several image sets are displayed. First (from left to right) is the image set acquired using an energy window around the isotope peak. Next is an image set acquired using an energy window placed so as to accept scattered photons. Below this image are controls which can be used to determine the fraction of scattered counts that will be used to correct the peak images. You can choose from preset values in the dropdown list, or type any value into the textbox. This scatter fraction is subtracted from the peak images, and the result is displayed in the rightmost image location. A checkbox below this image is used to turn on (checked) or off (unchecked) the filtering of the subtracted image.

Resolution Compensation

The **Resolution** button on the lower left of the main ERTb screen is used to change settings that relate to resolution compensation. When selected, this button creates a display on the right side of the screen, as shown in Figure 2-28.

The resolution compensation QC screen includes a checkbox in the upper left corner. If checked, this indicates that attenuation correction will be applied to the study. This correction is collimator and system specific.

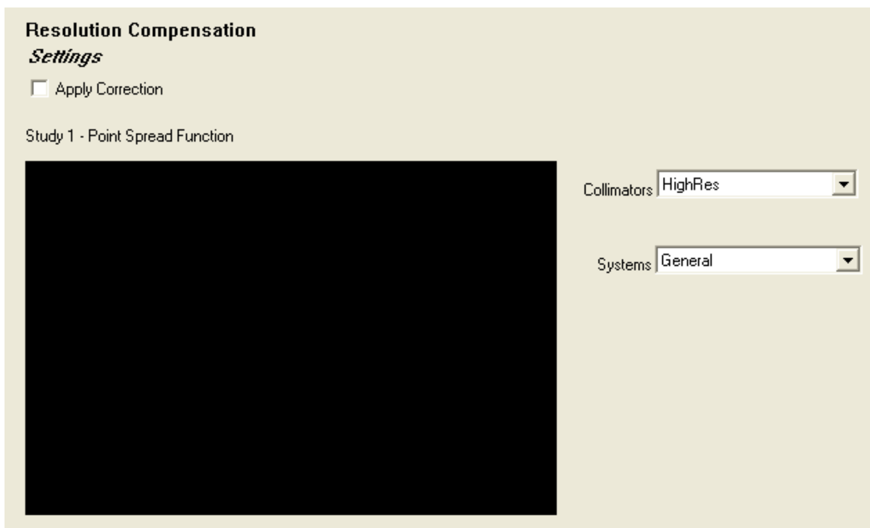

Figure 2-28. The interface for setting up resolution compensation for Study 1. There is a similar image display and similar control options for Study 2.

On the right side of this display are two dropdown lists which together characterize the camera system on which the images were acquired. Once the collimator and detector system is specified, the corresponding point spread function is displayed in the image area.

Deconvolution of Septal Penetration

The **DSP** button on the lower left of the main ERTb screen is used to change settings that relate to Deconvolution of Septal Penetration. When selected, this button creates a display on the right side of the screen, as shown in Figure 2-29.

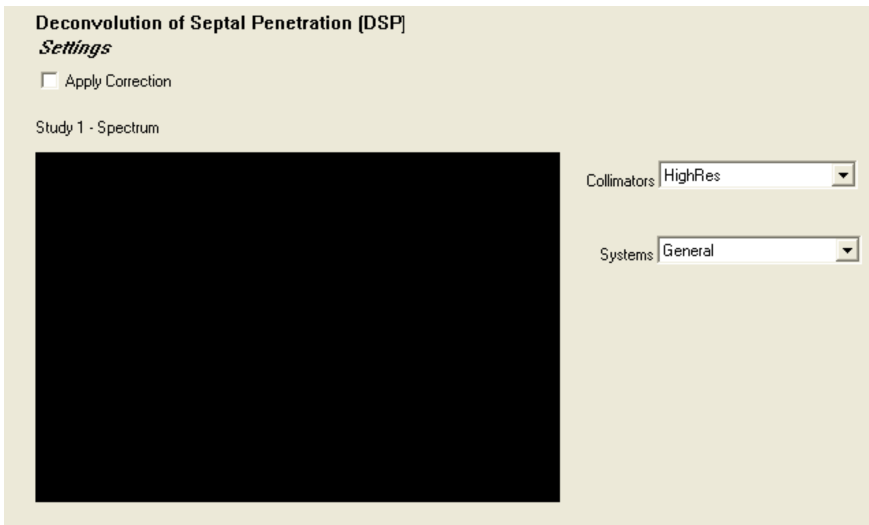

Figure 2-29. The interface for changing settings related to Deconvolution of Septal Penetration for Study 1. There is a similar image display and similar control options for Study 2.

The DSP QC screen includes a checkbox in the upper left corner. If checked, this indicates that attenuation correction will be applied to the study.

Like resolution recovery, DSP is dependent on the collimator and acquisition system. Two pulldown lists are used to indicate the collimator and detector system used to acquire the images. The corresponding energy spectrum is then displayed in the image area.

Reviewing Reconstructed Images

The review screen shows transaxial slices from Study 1 and Study 2, in the first two rows. These images are the output of the reconstruction step, and reflect the characteristics of the recon method and the filters applied. The remaining rows show Study 1 and Study 2 short axis slices, vertical long axis and horizontal long axis slices.

Certain acquisition artifacts and camera quality control issues can be seen most clearly in transaxial images. The images are oriented so that the viewer is at the foot of the patient, looking toward the head, as in Figure 2-30.

Transaxial Display Orientation

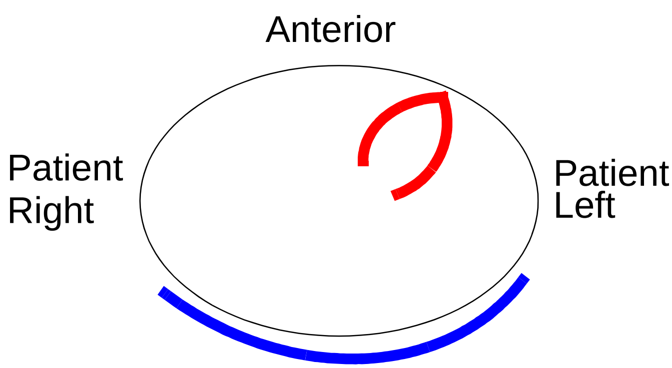

Figure 2-30. The orientation of transaxial images in ERTb. The oval shape is the body outline, and the red shape represents the left ventricle. In this example, the acquisition position of the patient is supine; the blue arc is the location of the scanning table.

Re-oriented vertical long, horizontal long and short axis images reflect the choice of angles made by the computer or by the user. They can be visually compared to make sure the processing of the two studies is comparable. Acquisition and camera quality control issues can sometimes be seen on these images as well.

Images are oriented for display according to the Americal College of Cardiology guidelines. The orientation is summarized in Figure 2-31.

Oblique Display Orientation

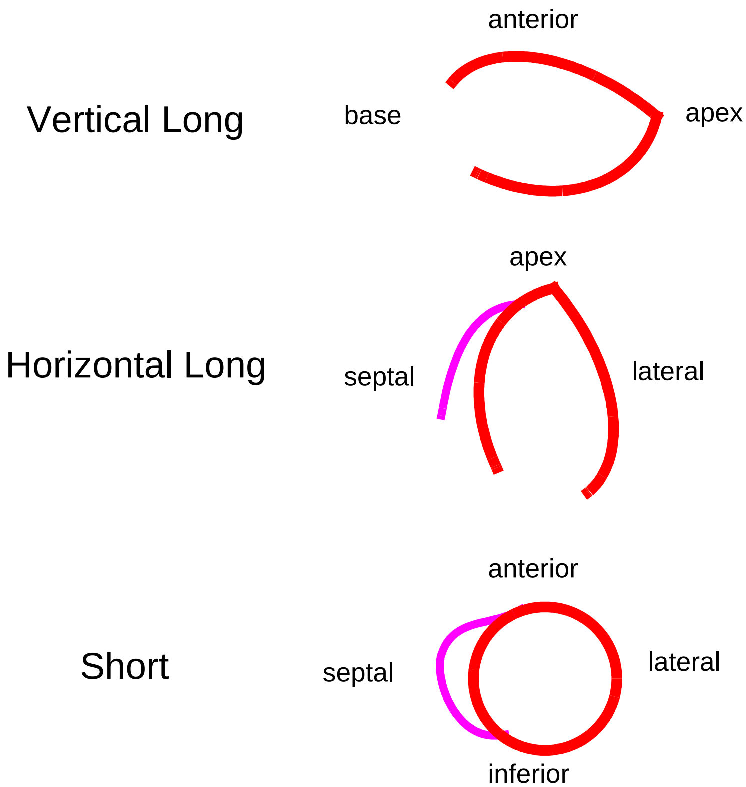

Figure 2-31. The orientation of oblique angle images in ERTb follows the ACC guidelines. In this diagram, the red shape is the left ventricle and the purple shape is the right ventricle. Images are displayed in this manner whether the acquisition position of the patient was supine or prone.

Quality Control

The **Quality Control** button on the main interface displays a set of images and other items related to a general quality control review. This screen is shown in Figure 2-32. This feature is partially implemented.

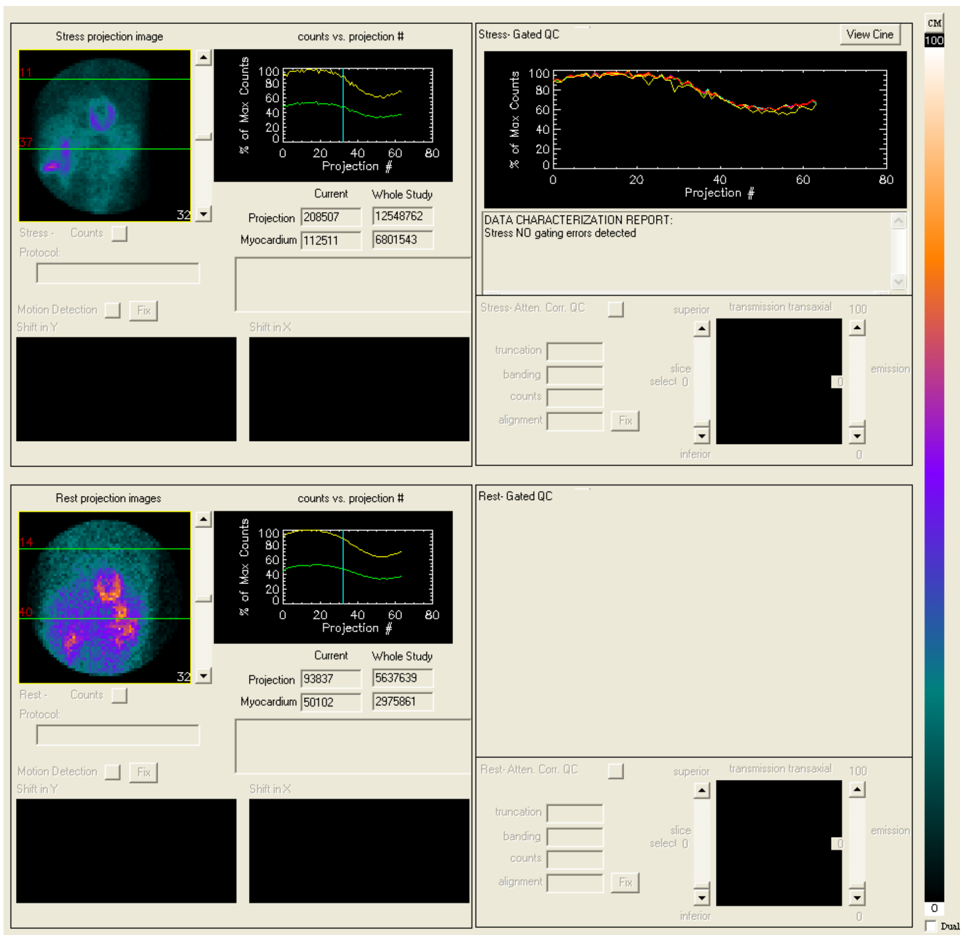

Figure 2-32. The Quality Control screen. Each study’s count density, ECG gating integrity and attenuation correction can be reviewed for appropriateness.

For each study, a quality control summary is provided for each of the following areas:

- Study count density
- ECG Gating quality
- Attenuation Correction

Count Density QC

Counts in the study are summarized in several ways, as illustrated in the expanded portion of the QC screen shown in Figure 2-33.

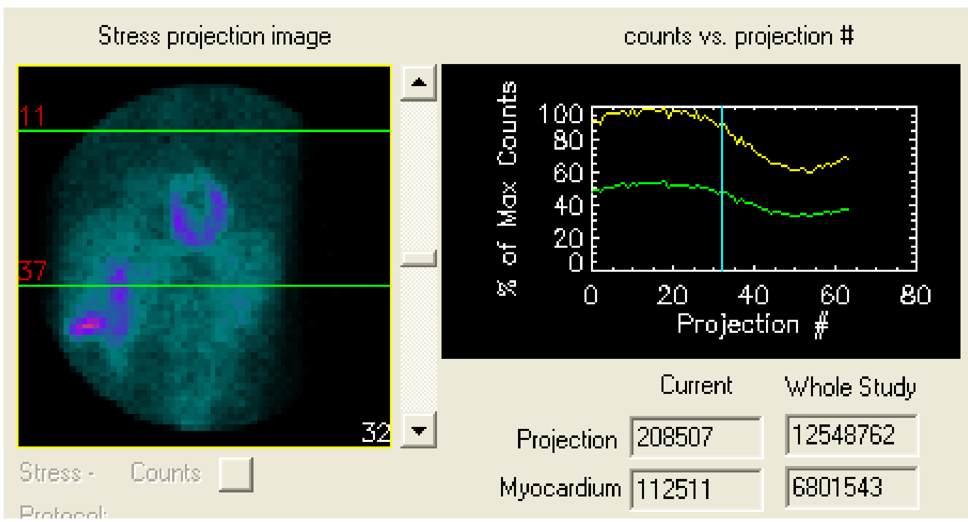

Figure 2-33. Enlarged portion of the Quality Control screen, showing a summary of count density in Study 1. The colors of the box areas correspond to the colors of the curve plots: green for the area within transaxial limits, and yellow for the entire frame.

A left anterior oblique projection image is displayed. This is the angle which shows the closest view to the left ventricle. As shown in Figure 2-33, the green box is the same vertical height as the reconstruction limits, and as wide as the whole image matrix. These counts cover the area of the left ventricular myocardium, that is, the transaxial volume that was reconstructed, and are plotted in green vs. projection angle on the graph to the right of the image. The yellow box also shown in the figure, is the size of the whole image matrix. Counts in this box are counts in the entire projection, and are plotted in yellow vs. projection angle on the same graph to the right of the image.

Below the graph is a table of count values. The column labeled **Current** holds the values for the particular projection image seen at the left. The column labeled **Whole Study** holds the sum of all projections. The row labeled **Projection** corresponds to the yellow box, and the row labeled **Myocardium** corresponds to the green box, which encompases only the myocardial area.

The same count summary is given for Study 2.

ECG Gating QC

Maintaining the integrity of ECG gating is important for later analysis of both function and perfusion. The main QC screen includes the output of a Gated Quality Control tool (GQC) which analyzes the counts from each gated image set, plots counts vs. projection angle, and provides a textual conclusion as to whether there is a gating error and whether it is serious.

An example of GQC output is shown in Figure 2-34. In addition to the curve plots for each gate, the projection images for each gate can be displayed using the **View Cine** button. buttons are provided to control the cine image display. This allows the cine to be started and stopped, its speed to be adjusted, and for the images to be stepped through one at a time. Images can be stepped forward using the **Step F** button, and reversed using the **Step R** button.

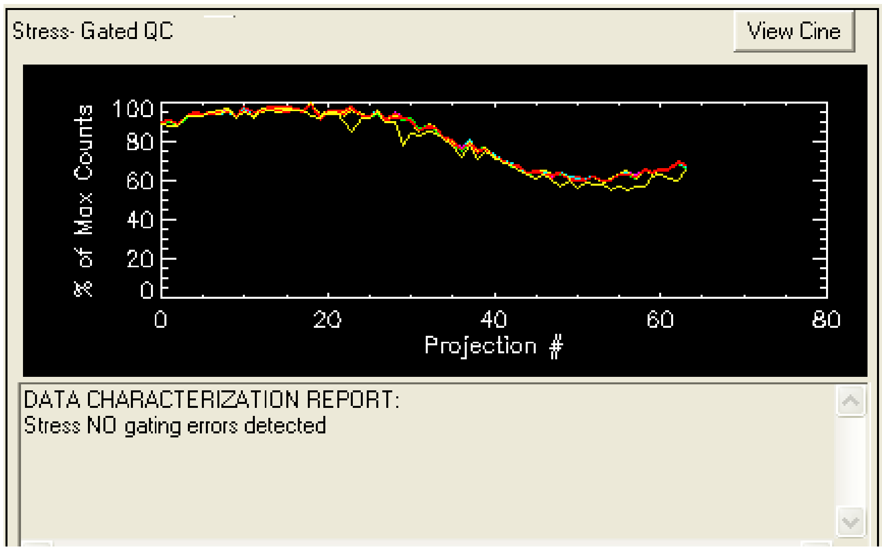

Figure 2-34. The Gated Quality Control output, displayed on the main QC screen.

Attenuation Correction QC

Quality control of the transmission study is a critical part of accurate attenuation correction (AC). In ERTb, the transmission acquisition is subjected to several integrity checks, and the results of these are displayed on the main QC screen, indicating briefly whether the test was passed, and if not giving its status. For example, counts in the transmission study could be low, but not so low as to compromise the correction. If the transmission source is old, counts could be very low and, in this case, the Counts test result will be reported as “critically low”.

An expanded part of the screen, showing the AC QC, is displayed in Figure 2-35.

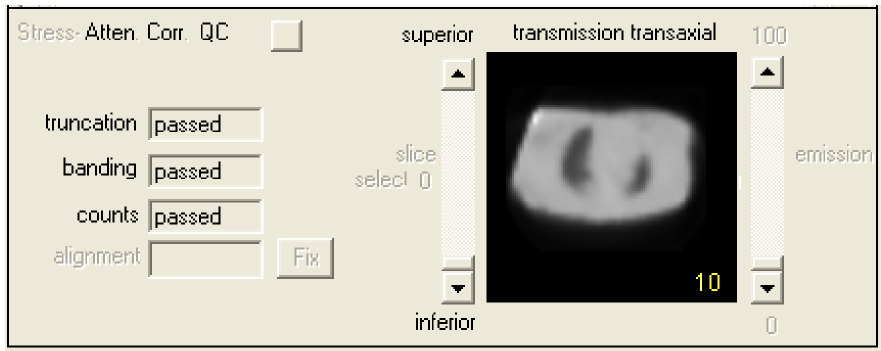

Figure 2-35. .The Attenuation Correction Quality Control review, part of the main QC screen for ERTb.

The transmission transaxials are displayed, with a slider control for stepping through the slices. This provides a visual indication of any image truncation that is present, and of patterns that suggest a low count transmission that may result in inadequate attenutation correction.

Motion QC

If motion correction was applied to either study, the X-Shift and Y-Shift summary plots will be shown on this screen, as they were on the Motion Correction screen.