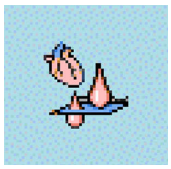
8 Dynamic Myocardial Perfusion



The **Dynamic Myocardial Perfusion (DMP)** application provides automatic and manual tools to help visualize and assess cardiac images, focusing on the left ventricular myocardium: specifically providing quantitative myocardial blood flow measurements for CT images. The application also calculates measurements of Perfusion, Peak Enhancement, Time To Peak, and Blood Volume.

The application supports ECG-gated dynamic (repeated) axial scans focusing on the left ventricular region of the heart.

WARNING

When loading images into the application, all images which contain 16 bit data are converted into 12 bit images. (Therefore, when the rescale intercept equals -1000, Hounsfield Unit values above 3095 are displayed as 3095, and when the rescale intercept equals -1024, Hounsfield Unit values above 3071 are displayed as 3071.)

Suggested Scan Protocol

Parameter	Suggestion
ECG	Gated Step & Shoot Cardiac with zero increment, centered around the LV
Detector Configuration	64x1.25mm
Targeted Cardiac Phase	Typically 40 or 45
kVp	80 – 100
mAs	40 – 60 (with 100 kVp); 60 – 80 (with 80 kVp). To be optimized accordingly.
#shots	~30
Cycle time	0.5 sec or 1.1 sec. 0.5 sec will scan every cardiac cycle, whereas 1.1 sec will scan every alternate cardiac cycle for the heart rates encountered.
Reconstructed Slice Thickness	2 mm
Reconstruction Kernel	CB/XCB (or CA in case of heavy patients)
iDose^4 Level	If iDose is available.

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Parameter	Suggestion
FOV	• Plan from the calcium scoring scan (if performed) or from the locator scan. • Typically 150 – 200 • In iCT V3.2, the smaller the FOV, the greater the reconstructable length. For example, FOV of 150 provides a reconstructable length of 6.8 cm, decreasing to 6.4 cm at FOV of 200. This is because x-rays are ON only for about 240-degrees, causing incomplete data at the edges; all reconstructions are therefore partial angle-based (240-degrees). • In iCT 4.1, the FOV is enabled to reach a reconstructable length of 8 cm for all FOVs.
Jog Mode	No jog mode scans are allowed for DMP.

Application Stages

There are two stages in the application:

- **Review and Verify**.
- **Perfusion Maps**.

Indications for Use

The Dynamic Myocardial Perfusion (DMP) application provides automatic and manual tools to help visualize and assess signal intensity differences (in Hounsfield Unit) focusing on the left ventricular myocardium, providing quantitative myocardial perfusion measurements for CT images.

Launch DMP

1. From the **Directory** find and select the desired **Study** and **Series.**
2. Select the **CT DMP** icon from the menu.

3. The application opens in the **Review & Verify** stage.

Review & Verify Stage

Upon loading, the application creates a registered series from the original dataset and attempts to find an **arterial input** pixel to be used as the reference Time Attenuation Curve.

NOTICE

All steps performed in this stage should be performed on the registered series.

DMP Review & Verify Options and Tools

Use the following options and tools (in the upper tool box) to modify the view and perform analysis.

Orientation

You can change the image orientation between the General Axes and the Cardiac Axes modes. Click the down arrow to switch between the two orientation modes:

- **General axes.** The general axes are the standard anatomical orientations: axial; coronal; and sagittal.
- **Cardiac axes.** The cardiac axes orient the views of the heart as follows: short axis; horizontal long axis (4 chamber view); and vertical long axis (2 chamber view).

Use the Flip button to flip the active volume viewport 180 degrees.

Flip

Use this button to flip the image in the main viewport right to left.

Relate

The **Relate view ports** and **Relate scenes** tools can help orient yourself.

To use, select either **Relate view ports** or **Relate scenes** and click on any pixel in any viewport. The location of that pixel is automatically marked on all the other view ports.

On/off ECG

If an appropriate ECG is included in the study, click the button to display the ECG viewer. For information on using the ECG viewer, see the **Cardiac Viewer** section.

Cine Tool

The cine tool allows reviewing all images of the perfusion data set. Each axial slice can be scrolled through all time points. It is recommended to use this tool after registration which minimizes the presence to anatomical motion, if any. Select the number of images (this also affects the number of images displayed) and the speed.

Cardiac Overview Viewing Modes

Verify short axis images, either by displaying all short axis images or by selecting a region of short axis. When examining a region of the short axis, scroll the displayed images by scrolling the short axis cMPR image on the bottom right viewport.

Use the **Show Short Axis Indication** button to show or hide the reference image on the bottom viewport shows the examined region.

Use the **Examine Myocardium** button to display several short axis images covering part of the myocardium. Scroll through the images to examine the entire myocardium.

The images that are displayed cover the upper part of the series as calculated as:

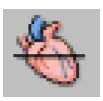
$y = \frac{Thickness\ of\ Each\ Short\ Axis\ Image}{Minimum\ Increment * Number\ of\ Short\ Axis\ Slices}$	y	Entire area along long axis covered in **Examine Myocardium** mode

NOTICE

Toggling between **Examine Myocardium** and **Myocardial Overview** can also be done using the right-click menu.

Use the **Myocardial Overview** button to display several short axis images covering the entire myocardium.

Single Viewing Mode



Use the **Single Slice** button to display a large single-slice viewport. Scroll through the images to examine the entire Series (including the axial image both in time and z-location). This should be done both in average rendering mode (time + z-location) and in tMIP rendering mode (only z-location).

On/off ECG

If an appropriate ECG is included in the study, click the button to display the ECG viewer. For information on using the ECG viewer, see the **Cardiac Viewer** section.

Cardiac Orientation (Right-click Option)

To change the default layout (axial image with reference coronal and sagittal images) to the **Cardiac** orientation, which include short/long axis views, right click on the image and select the appropriate option from the **Cardiac Orientation** menu.

When changing to cardiac orientation, it is possible to use each of the orientations as the main orientation.

NOTICE

The active table may be added to the clipboard using **Ctrl + C** or by right-clicking on the table and selecting copy. The measurements may then be pasted into common document types, including plain text, Microsoft Word, and Microsoft Excel documents.

DMP Review & Verify Common Tools and Functions

See **Report**, **Film**, **CT Common Processes** and **CT Common Tools** for information on using common options, tools, functions, and processes.

Common Tools

Common tools provide many basic functions, including saving, filming, reporting, scrolling, measurements/annotations, panning, zooming, rotating, and windowing.

Common Functions

To access additional functions, click the down arrow in the tab window, or hover the mouse over the tab window. The list of available functions displays.

- **Bookmarks**. This function allows you to access Bookmarks, if any are saved.
- The **Batch** function allows you to create a series of sequential images for viewing, saving, reporting and filming purposes.

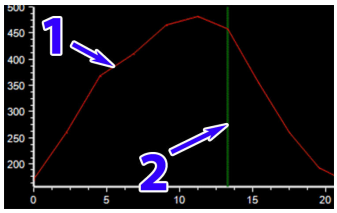
Key Images

Save groups of images that can be reviewed in any system supporting the defined standard. See **Instructions for Use** > **Directory** > **Key Image Notes** for more information.

Mark DMP Arterial Input

Upon loading, the application attempts to detect an arterial input automatically.

Arterial Input - Time Attenuation Curve

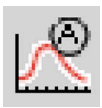


The red line (item 1 in the image) represents the arterial input. The green line on the arterial input graph (item 2) represents the current time point shown in the main viewport. The line is adjustable and when it is scrolled to a certain time point, the image in the main viewport shall be updated accordingly.

NOTICE

The arterial input should be within the left ventricle and should have a distinct Time Attenuation Curve (TAC).

Automatic Detection



Use this button to perform automatic arterial detection.

Manual Detection

Manual detection of the arterial input is possible using either an **Ellipse** (average TAC for a region) or a **Cursor** (highest enhancement pixel TAC within a region).

Manual detection calculation:

Average Max Value - Min Value

Select either **Cursor** or **Ellipse** and mark the artery. The recommended location for marking the artery is within the left ventricle.

WARNING

Verify the correctness of the segmentation and labels, (manual visualization) and correct it manually if required.

Verify and Correct DMP Cardiac Axes

Upon loading, the application attempts to detect the axes defining the left ventricle. These are defined based upon four reference images: 3 planes of the long axis and one cross sectional image of the short axis. The base and apex of the left ventricle can be reviewed and corrected on each of the long axis reference images, and the planes of the long axis can be rotated using the **spoke wheel** on the short axis cross sectional image. Once the axes are reviewed and corrected, select **Accept Axes**.

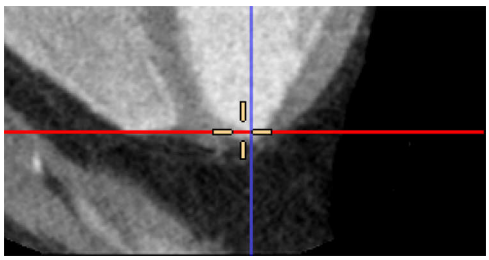
NOTICE

You must verify and correct, if necessary, the axes before continuing.

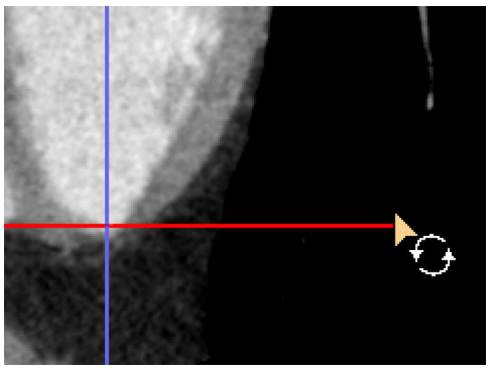
The Cardiac Axes are generated so that the cross-hairs of the long axes views cross the left ventricle through the apex and the mitral valve. After you examine the Cardiac Axes, if you want to adjust the crosshairs, use the Correct Axis function.

You can zoom and pan the viewport to better observe the crosshairs. You can also expand any viewport to full size by double-clicking in it. Double click again to return to the original layout.

1. With the Correct Axis function active (the button appears depressed), move the mouse pointer toward the crosshairs you want to adjust.
2. The pointer changes to a crosshair pointer.

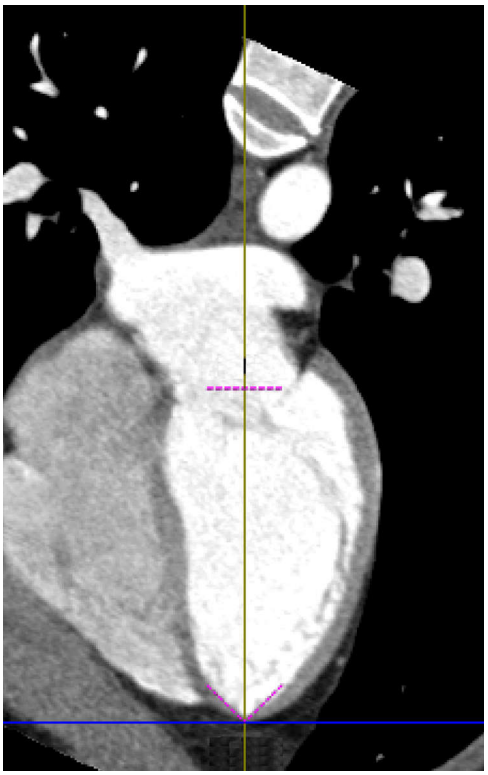


3. Holding down the left mouse button, drag the crosshairs to the desired position.
4. Repeat the Correct Axis procedure in other viewports, as needed.
5. If correcting the cross-hairs requires rotating them, move the mouse pointer to the edges of the cross-hairs. The cursor changes to a rotation cursor, making it possible to rotate the cross-hair.



Correct DMP Valve and Apex Planes

Examine the position of the base and apex planes, and correct them if needed.



Correct the apex setting by dragging the Apex (V-shaped dashed line) to the correct position. If necessary, correct the Mitral valve plane by dragging Base (straight dashed line) to the correct position.

Configure DMP Filter Settings

If you feel that the data is noisy and needs filtering (by visual inspection), use the **Filter Settings** tab. There are three available filter types:

Spatial Filter

The spatial filter is designed to reduce image noise in the spatial domain, while at the same time maintaining the edges of the relevant structures. Click on the button to turn the filter on. The spatial filter has a slider controlling the aggressiveness of the filtering (higher number -> the filtering is more aggressive). Default setting is 0.65.

Temporal Filter

The temporal filter is designed to reduce noise in the image data over the adjacent temporal positions. Click on the button to turn the filter on.

Spatio-Temporal Filter

This filter is a combination of the Spatial & Temporal Filters. Click on the button to turn the filter on.

Loading Settings

Use this tool to choose specific loading settings for the data, including the workflow for registration and filtering (default does not include filtering). Define the modified **Loading Settings** as default if to have the application load the new settings upon relaunch.

DMP Perfusion Maps Stage

In the **Perfusion Maps** stage, assess the perfusion of the various regions of the left ventricle myocardium. The perfusion analysis is done based upon the perfusion analysis used in the **Functional CT** application's **max slope** method. It provides a long and short view, in addition to four distinct perfusion maps:

- Perfusion
- Peak Enhancement
- Time To Peak
- Blood Volume

The maps can either be viewed altogether or toggled using the upper toolbox controls. The perfusion maps have several different color schemes, which can be toggled using the RMB context menu. **Cardiac** is the default color scheme, and **Thalium** color scheme is also used.

On the bottom of the default layout there are two viewports:

- Arterial TAC.
- ROI statistics table for short axis slices.

DMP Perfusion Maps Options and Tools

Use the following options and tools (in the upper tool box) to modify the view and perform analysis.

Layout

The currently active layout is displayed as the icon. Click the down arrow to select one of the alternate layouts:

- All Perfusion Maps
- One Perfusion Map + 2 Vertical axes
- Short Axis large + 4 Perfusion Maps
- Long Table

The **Layout Manager** allows you to perform various layout (display) management functions.

On/off ECG

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DMP Perfusion Maps Common Tools and Functions

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Draw DMP Myocardial ROIs

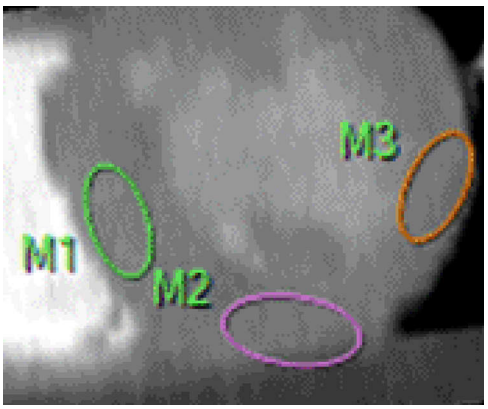
The Myocardial ROI allows drawing ROI in various shapes and observe the perfusion results for them.

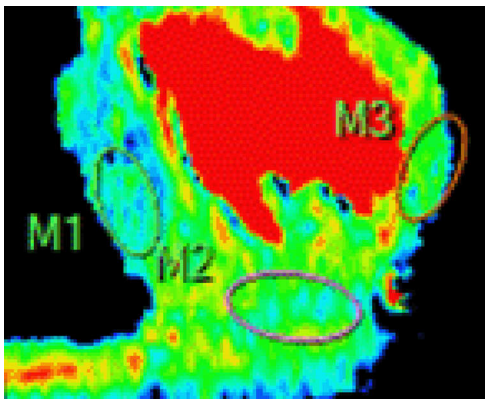
Draw several ROIs on a certain short-axis slice to cover most of the range of Myocardium in that slice with an emphasis.

Repeat the process with any short slice axis that seem to have any deficits in perfusion.

When a ROI is drawn at a certain location on a specific time point, it is automatically drawn on all other time points at that location. The perfusion calculations are based on location of ROI in all time points. When moving the ROI in one time point, the application automatically moves the ROI on all time points.

The application also draws the ROI on all perfusion maps, and updates the maps if an ROI is moved.





Make Special

If additional registration corrections are needed, right click on an ROI and select **Make Special** from the menu: An additional ROI is drawn only on active time point. This ROI replaces the original ROI for the activate time point, which remains visible, and moving this ROI shall only affect active time point. To remove a special ROI, right click and select **Remove Special**.

NOTICE

As perfusion maps are for entire scan duration, and not for specific time point, the **Special** ROI created on the short axis image does not appear on perfusion maps.

Disable

To exclude a certain time point from ROI statistics table, without changing the ROI for other time points, right-click on the ROI and select **Disable**. The ROI remains visible on all time points, but the ROI graph will exclude the time point.

ROI Calculation Results

For each ROI, the perfusion parameters are calculated by the algorithm based upon the **max slope** analysis method. The results are displayed both in a table and in a graph.

Configure DMP Perfusion Options

This tab allows controlling the parameters according to which the application defines the range of pixel data it uses for calculation. Changing these parameters will result in a change of the perfusion pixels shown within the perfusion maps.

By default, the application removes air and bone which have an average HU number above/ below certain threshold.

It is possible to choose to remove vessels, which are defined (by default) as pixels which have an enhancement of more than 20% of reference artery.

When changes are made, the ROI statistics table updates to exclude/include the relevant tissues.

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WARNING

Verify the correctness of vessel removal.

DMP Perfusion Calculation

Arterial perfusion: perfusion during arterial phase:

$$Perfusion = \frac{Flow}{Volume} = \frac{\frac{d}{dt}\left[c(t)\right]\Big|_{\max}}{a(t)\Big|_{\max}}$$

Peak Enhancement

$$Peak\ Enhancement = MaxVal - MinVal$$

Time to Peak

$$Time\ to\ Peak = Time\ of\ Local\ Peak - Time\ of\ Start\ of\ Bolus\ Arrival\ in\ LV$$

Blood Volume

Philips

$$Blood\ Volume = Computed\ Blood\ Volume * \frac{Hematocrit\ Scale\ (85)}{CbvFactor}$$