# 2 MR T1 Perfusion

This postprocessing package is meant to evaluate T1 perfusion studies and generate numerical and graphical results and maps.

T1 perfusion studies are based on the fact that contrast agent shortens the T1 relaxation times of tissues.

**Valid imaging series**

A valid imaging series for the MR T1 Perfusion package is a T1w dynamic perfusion imaging series where a stack of slices is repeatedly acquired over time. It is a series that holds slices and dynamics. The MR T1 Perfusion package requires at least 4 dynamics.

This type of series allows to observe the changes of the T1 relaxation time and in such a way the contrast-uptake.

## Indications for Use

The MR T1 Perfusion post-processing software is designed to evaluate Time Intensity Curves (TIC) of a T1 signal enhancement series.

## User Interface

### Screen layout

The MR T1 Perfusion package has a default layout of task guidance panel and toolbars, and four viewports. The viewports display the following views:

- Source image in the middle of the imaging volume.
- In real-time calculated Parametric T1-maps.
- Subtracted Image Series, Table Viewer (numerical results), or Anatomical Viewer (reference imaging series).
- Graph Viewer (graphical results) or Anatomical Viewer (reference imaging series).

**Switch between Subtracted Image Series and the Table Viewer**

1. Click the right or left arrow in the upper right corner of the viewport.

**Switch between Graph Viewer and Anatomical Viewer**

1. Click the 'Graph Viewer' tab to switch to the Graph Viewer.
2. Click the 'Anatomical Viewer' tab to switch to the Anatomical Viewer.

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## Task Guidance

Similar to all packages on the IntelliSpace portal, also the MR T1 Perfusion package provides a Task Guidance panel in the left part of the screen.

## Toolbar

**Color LUT (Look-Up Table)**

- To select the color look-up table for the maps.

    Possible settings are: 'Blue to Red', 'ASIST' and 'Gray'.

| Color LUT | Minimum value | | | | Maximum value |
|---|---|---|---|---|---|
| Blue to Red | Blue | Green | Yellow | Orange | Red |
| ASIST | Black | Light blue | Green | Yellow/ Orange | Red |
| Gray | Black | | Gray | | White |

The ASIST LUT is a LUT specifically designed for acute stroke imaging. The Acute Stroke Imaging Standardization Group - Japan (ASIST-Japan) is a group that conducts medical research projects dedicated to the standardization of brain computed tomography (CT) and magnetic resonance imaging (MRI) in the clinical setting of acute cerebral stroke.

### Layout

To select another screen layout, click **Layout** and select a layout option. You can also edit the current layout and save it as a preset using the **More** menu. Custom layouts that you have saved as presets are also available in the **Layout** list.

### Follow Mouse

Once enabled, this function displays real-time results for the current voxel (indicated by the current position of the cursor).

### Viewing Tools

**Mirror**

This function mirrors the image(s) (Right <-> Left)

**Flip**

This function flips the image(s) (Up <-> Down)

 **Rotate Clockwise**

This function rotates the image(s) clockwise

 **Rotate Counter-Clockwise**

This function rotates the image(s) counter-clockwise

## More Functions within the Perfusion packages

In IntelliSpace Portal MR packages, the most important functions can be performed via the Task Guidance and the toolbar. However there are more functions which you can access via the right mouse menus.

For more information, see section "Right mouse menus" on page 12.

### Right Mouse Menu for T1 Perfusion

**NOTICE**

The 'Modify the Results Display' function is only available in the Permeability and the two perfusion packages.

### Set as Subtraction Reference

- To select a dynamic other than the first one as subtraction reference.

For subtraction purposes, by default the first dynamic (precontrast) is selected as reference. A different dynamic can be used as reference via this function.

**NOTICE**

This function is applicable only to T1 Perfusion.

# Workflow

## Launch the MR T1 Perfusion package

▷ In the 'Directory' tab of the activity bar:

1. Select a suitable perfusion series.

 2. Click 'MR T1 Perfusion'.

   The MR T1 Perfusion package opens.

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## Scroll through images

### Through dynamics

1. In the image viewport, drag to the left or to the right.

### Through slices

1. In the image viewport, drag up- or downwards.

### Through maps

1. In the map viewport, drag to the left or to the right.

**NOTICE**

For the further workflow, utilize the task guidance in order to make optimal use of the package.

The Task Guidance window is in the left part of the screen.

**Apply Spatial Smoothing**

- To spatially smooth the resulting maps.

Possible settings are: None (no smoothing), Weak, Medium or Strong.

The strength of the smoothing setting determines the size of the kernel used to average neighboring voxels.

Spatial smoothing smooths the maps and the original images. In such a way, spatial smoothing has an effect on the numerical results.

## Define the Mask

This workflow step serves to adjust the mask and to enable the display of the mask while adjusting.

Setting a threshold mask will exclude background pixels from the functional map calculations. All pixels with values below the mask value will be displayed blue. Only pixels with intensity above the mask value are used for the calculations, colored areas will be excluded from the calculation.
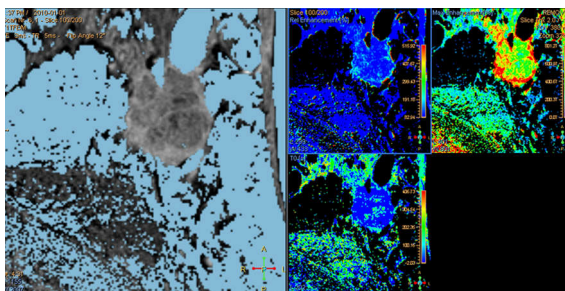
1. Drag the slider to define the mask.

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**Fig. 4:** Step 2: The mask is overlaid to the current source image.

**Alternatively:**

You may also drag the right mouse button in the images to change the mask.

## Select the Desired Maps

You can select the maps in the task guidance panel for real-time calculation and display, and for the generation of new imaging series.

1.   Click the checkbox of a map to select/deselect this map.

The display of the real-time calculated maps will be updated accordingly.

## Select Series for Anatomical Viewer

Upon startup of the package, the Anatomical Viewer is empty. However an additional imaging series in the Anatomical Viewer might help during navigation through the data set and in order to draw ROIs.

Any type of imaging series can be loaded into the anatomical viewer. The orientation of the series in the Anatomical Viewer is always identical to the orientation of the source image and the map. This might require the calculation of real-time Multiple Planar Reformats.

**NOTICE**

When you load an imaging series with an orientation different to the source image into the Anatomical Viewer, the series in the Anatomical Viewer will be a real-time Multiple Planar Reformat (MPR).

Always be aware that the imaging parameter of this series determine the image quality of the resulting MPR. Low resolution imaging series will result in blurry MPRs and might hamper the workflow.

**To load an imaging series into the Anatomical Viewer**

1.   Click the **Anatomical Viewer** tab to switch to the **Anatomical Viewer**.

2.   Right-click the **Anatomical Viewer** and click **Select Series** from the right mouse menu.

3.   Click on a series in the **Select Series** window and click **OK** to confirm the selection.

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4.  You can also load a series by dragging and dropping a series.


**Tip**

**When you save a layout, the series displayed in the viewer at that time is saved with the layout. When you reload the layout for another case, the same series is also reloaded in the viewer. You can save a layout using the More menu in the task guidance panel.**


## Draw ROI

You can draw a ROI to focus on a specific area, e.g. a lesion.

For information on how to draw, modify and rename a ROI, see section "Draw ROI" on page 15.
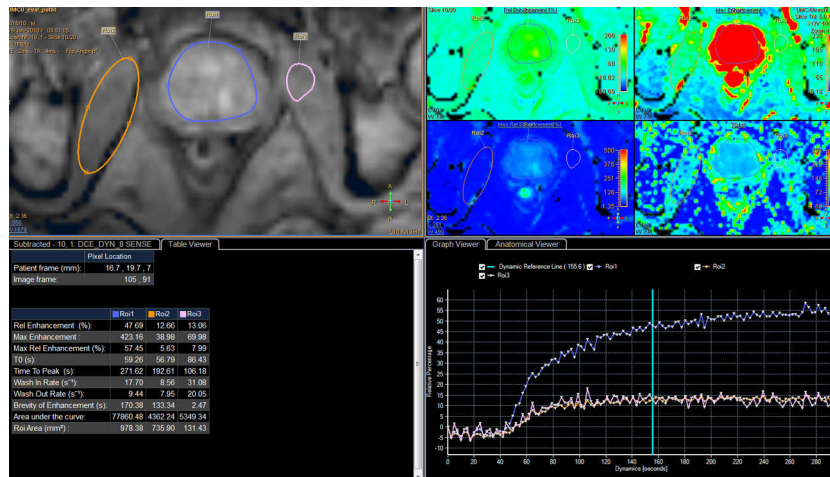


**Fig. 5:** Three different ROI types with numerical and graphical results. ROI1 - Spline Contour, ROI2 - Ellipse, ROI3 - Freehand Contour.

If desired, you can remove the last drawn ROI. Do one of the following:

- Press Ctrl+Z.
- Right-click the ROI and then click **Delete Last Drawn ROI** in the shortcut menu.

### More options

You can enable/disable the display of curves in the Graph Viewer.

1.  Check the checkbox 'Roi1', 'Roi2' or any 'Roi' in the Graph Viewer to enable the display of the related graph.
2.  Uncheck the checkbox 'Roi1', 'Roi2' or any 'Roi' in the Graph Viewer to disable the display of the related graph.
3.  To view the results with a fitted curve, right-click the Graph Viewer and click **Fitted Curve**.


## Select Underlay

You can select an MR series as underlay of the parametric maps allowing for better allocation.

In order to optimize the display you can also adjust the opacity of the overlaying parametric maps.

**NOTICE**

MR series are suitable source images. Secondary captures are not suitable because they are lacking in general geometry information.

The underlay is automatically reformatted to the geometry of the overlay. The resolution is determined by the resolution of the overlay in the preview viewer.

**Select Underlay**

1. Select an option:

   - **None**

     The parametric maps will be displayed without underlay.

   - **Source as Underlay**

     The source series will be displayed as underlay.

   - **Select Other Underlay**

     Browse to the series you would like to use as underlay and click **OK** to confirm. You can also load a series by dragging and dropping a series.

**Tip**

**When you save a layout, the series displayed in the viewer at that time is saved with the layout. When you reload the layout for another case, the same series is also reloaded in the viewer. You can save a layout using the More menu in the task guidance panel.**

**NOTICE**

There can be a mismatch between underlay and overlay also in the Anatomical viewer if there was any patient motion between the acquisitions of these series.

**Adjust the opacity of the overlay**

1. Drag the slider to adjust the opacity of the parametric maps.

You may also drag the right mouse button in the color maps to change the opacity of the overlay.
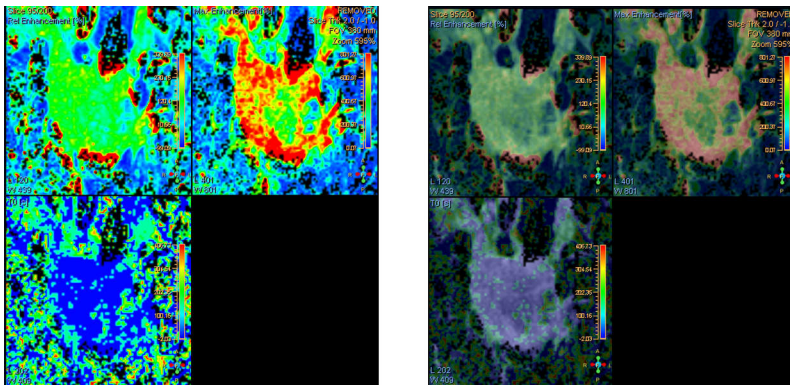
**Fig. 6:** Left: 100% opacity of the parametric maps. Right: 20% opacity of the parametric maps.

## Generate Series

You can generate a new imaging series containing the parametric maps and results as defined in the previously described workflow.

1. To generate a standard DICOM-compatible series, select **Generate Series** using the Secondary Capture option from the drop-down list, and then click the button.

2. Enter the name of the new imaging series in the **Name** box.

3. To generate a series as RGB images (high resolution color maps), select **Generate Series** using the Secondary Capture RGB option.

**Register Data While Saving**

Once enabled, this function performs registration when generating actual maps. In such a way image quality will most likely improve in the maps.

> **NOTICE**
>
> If the input data is unregistered, there can be a mismatch between the previewed and generated maps as the generated maps are calculated after registering the input.

# Results

The package calculates the following results:

**Graphical and numerical results**

- The graphical results present a **Time-Intensity Diagram** (intensity versus time).

  In 'Follow Mouse' mode, the graph correlates to a specific pixel and shows the intensity value (intensity) over the time for this pixel.

- The results will be provided as **parametric maps** and in a **table of results**.

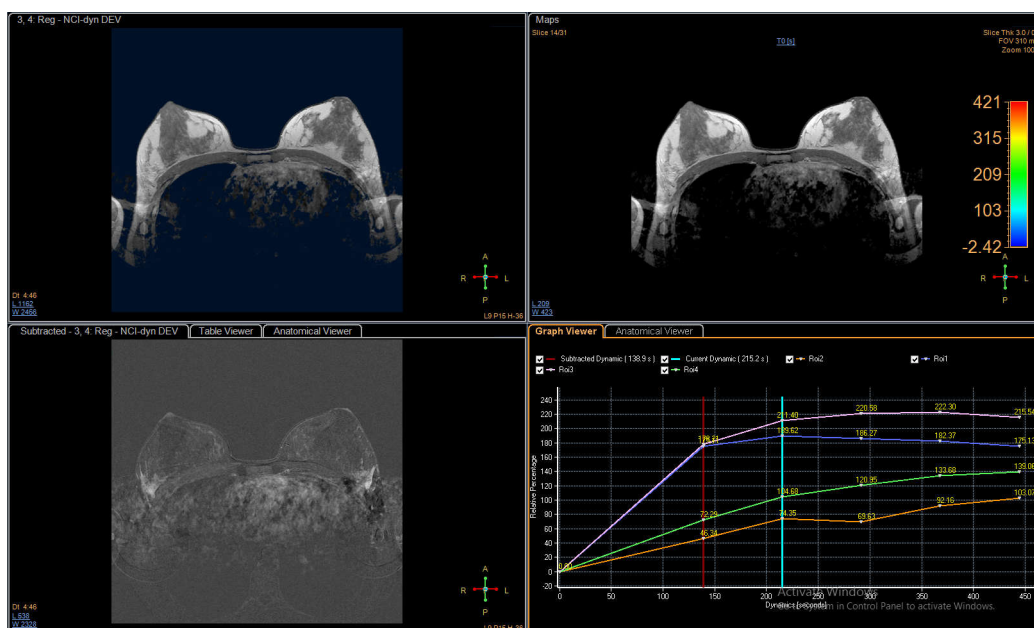  Scrolling through the maps, the type of the map is indicated in the map's series type field.

**Fig. 7:** Results screen: source image and maps with ROIs, Table Viewer and Graph Viewer. The vertical lines in the graph represent the variable dynamic and the reference dynamic

To draw a windowing ROI, right-click a map and then click **Draw Windowing ROI**. The color scale of the map is recalculated to display maximum color heterogeneity inside the ROI. You can draw windowing ROIs on each map independently.
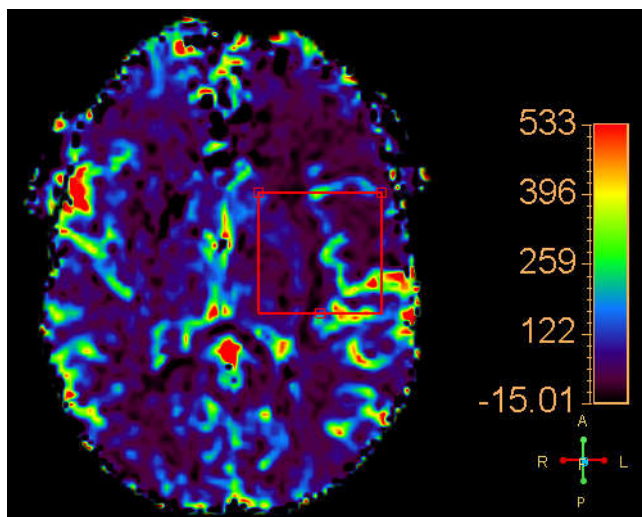


**Fig. 8:** Drawing a windowing ROI

**Measurement Type Selection**

To change the type of measurement for all parametric maps, right-click the results summary table and select an option.

- **Region Parameters (Factory default)**: The application calculates T1 parameters using the time intensity curve for the drawn ROI and displays the values in the table viewer.

- **Mean Voxel Parameters**: The application calculates the mean of all the voxels inside the ROI of the output parameters and displays the values in the Table Viewer.

The table heading is updated based on the selected type.

**Show ROI Statistics**

You can right-click the results summary table and choose to show ROI voxel statistics (or) select from More menu.

An additional numerical results table is displayed as floating window and display Maximum, Minimum, Median, Average and Standard deviation of the quantitative parameters for the ROI voxels with in the parametric maps.

When the number of columns in the table viewer exceeds default width or number of rows exceeds default height, the auto scroll is visible to allow the user to scroll to see all the columns and rows

**To export table results:**

1.  Select **Copy to Clipboard**, open either Microsoft Word or Excel and paste the contents from your clipboard into the application.

2.  Select secondary capture. A dialog box is displayed allowing you to select a file name, file format, and destination. You can save the series in DICOM format, or in non-DICOM format. If you select a non-DICOM format, you should additionally select a file system destination for exporting the table results.

**Relative Enhancement [%] (RELENH)**

- The signal enhancement of a pixel of certain dynamic relative to that same pixel in the reference dynamic. The reference dynamic is normally the first, pre-contrast dynamic. The reference dynamic can be set to another dynamic via the right mouse menu function 'Set as Subtraction Reference'.

$$\text{Relative Enhancement} = \left[ \frac{I(D)}{I(Dref)} - 1 \right] \times 100$$

**Fig. 9:** Formula

- where I(D) stands for pixel intensity of current dynamic and I(Dref) stands for pixel intensity of reference dynamic.

**Maximum Enhancement (MAXENH)**

- Difference between peak intensity S1 and S0.

**Maximum Relative Enhancement [%] (MAXRELENH)**

- Maximum of all relative enhancements over all dynamics.

**T0 - Time of Arrival [s] (T0)**

- Time at which the signal intensity increases for at least 20% compared to the baseline (referred to as initial signal intensity S0).

  The baseline is the average of the signal intensities of all timepoints before the contrast uptake starts.

- As long as the signal intensity doesn't exceed more than 20 % from the baseline, it will not yet be identified as the start of the contrast uptake (T0).

**S0 - Initial Signal Intensity**

- The baseline signal intensity S0 is the average of the signal intensities of all timepoints before the contrast uptake starts.

**Time to Peak [s] (TTP)**

- Time till contrast agent bolus reaches peak intensity.

**Wash-In Rate [l/s] (WASHIN)**

- Maximum slope between T0 and time of peak intensity T1.

$$\text{Wash-In} = \text{Maximum} \left[ \frac{I(D) - I(D-1)}{T} \right]$$

**Fig. 10:** Formula

**Wash-Out Rate [l/s] (WASHOUT)**

- Maximum slope between time of peak intensity T1 and the end of the measurement.

$$\text{Wash-Out} = \text{ABS} \left( \text{Maximum} \left[ \frac{I(D) - I(D-1)}{T} \right] \right)$$

**Fig. 11:** Formula

**Brevity of Enhancement [s] (BREVENH)**

- Time between point of maximum wash in rate and maximum wash out rate.

**Area under the curve (AREACURV)**

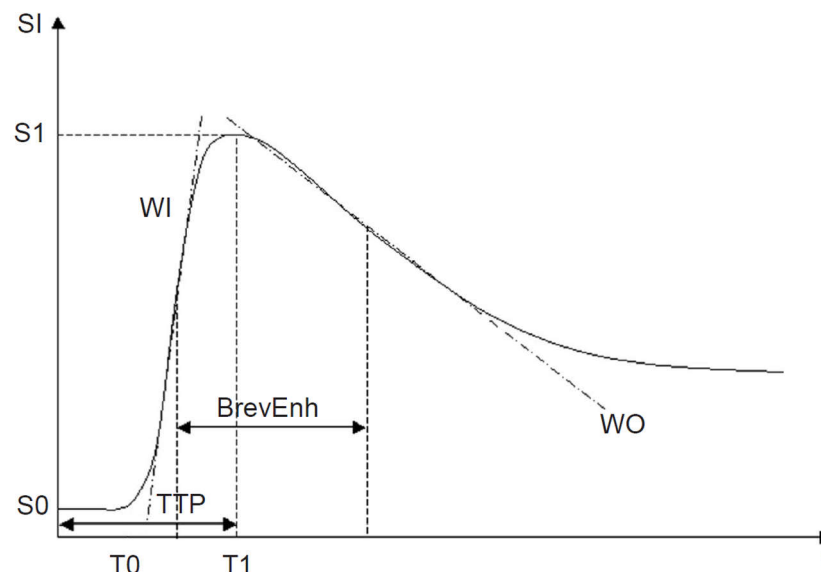Sum of all intensities under the curve.

**Graph characterizing parameters**



**Fig. 12:** T1 Perfusion - Results.

| Abbreviation | Description |
| --- | --- |
| SI | Signal intensity |
| t | Time |
| S0 | Initial intensity |
| S1 | Peak intensity |
| T0 | Time of Arrival (time of initial intensity) |
| T1 | Time of peak intensity |
| WO | Wash-Out Rate |
| WI | Wash-In Rate |
| TTP | Time to Peak |
| BrevEnh | Brevity of Enhancement |

## References

Kuhl, et al. "Breast neoplasms: T2* susceptibility-contrast, first-pass perfusion MR imaging". *Radiology*, No. 202 (1): 87-95, January 1997.

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