12 MR Cartilage Assessment

The Cartilage Assessment package can be used for the quantitative analysis of cartilage and cartilage lesions. It is based on the difference between T2 relaxation times of healthy and damaged cartilage.

Valid Imaging Series

A Multi-Echo Spin-Echo series with all echoes is required to analyze the T2 times in the Cartilage Assessment package. The analysis also requires a calculated T2 map, but if map calculation was not enabled in the ExamCard when scanning, a T2 map is automatically calculated when a series is opened. T2 maps are also calculated automatically when you open multi-vendor series in the application.

In order to provide good results, a certain minimum quality of data is needed. A preset procedure is available to generate such data (anatomy folder 'Knee Other').

Indications for Use

The MR Cartilage Assessment application is intended to assess the integrity of cartilage on MRI Data.

User Interface

Screen layout

The Cartilage Assessment (CA) package has a default layout of four viewports with toolbar and panels. The viewports display the following views:

- Source image in the middle of the imaging volume, 1st echo.
- In real-time calculated Parametric CA maps with color bar:
  - Shortest T2 values: dark red to red,
  - intermediate T2 values: yellow to green,
  - longest T2 values: blue.
- Numerical results.
- Graphical results.

Task Guidance

Similar to all packages on the IntelliSpace portal, also the Cartilage Assessment package provides a Task Guidance panel in the left part of the screen. The task guidance panel provides the following functions:

- Rectangular layered ROI

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Philips

- Curved layered ROI
- Optimize Color Overlay
- Generate Series

Follow the steps of the Task Guidance to make optimal use of the package.

The following workflow description is based on this Task Guidance.

NOTICE

In most of the IntelliSpace packages, the Task Guidance contains the recommended step-by-step procedure that you should follow. This is different with the Cartilage Assessment package.

The Task Guidance contains the most important functions, but not in a step-by-step procedure. Perform the required steps for optimal results for your scan and your needs.

NOTICE

Standard Measurements like retrieving a pixel value or measuring a distance can be performed via the Common Tools panel.

Toolbar

The toolbar functions are meant to customize the presentation of the T2 maps. The T2 values in the parametric maps are directly related to specific colors, and the color coding can be set to predefined values, but can also be adjusted according to everyone's needs.

Color Map

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

  Possible settings are: 'Rainbow', 'Reversed Rainbow' and 'Autumn'.

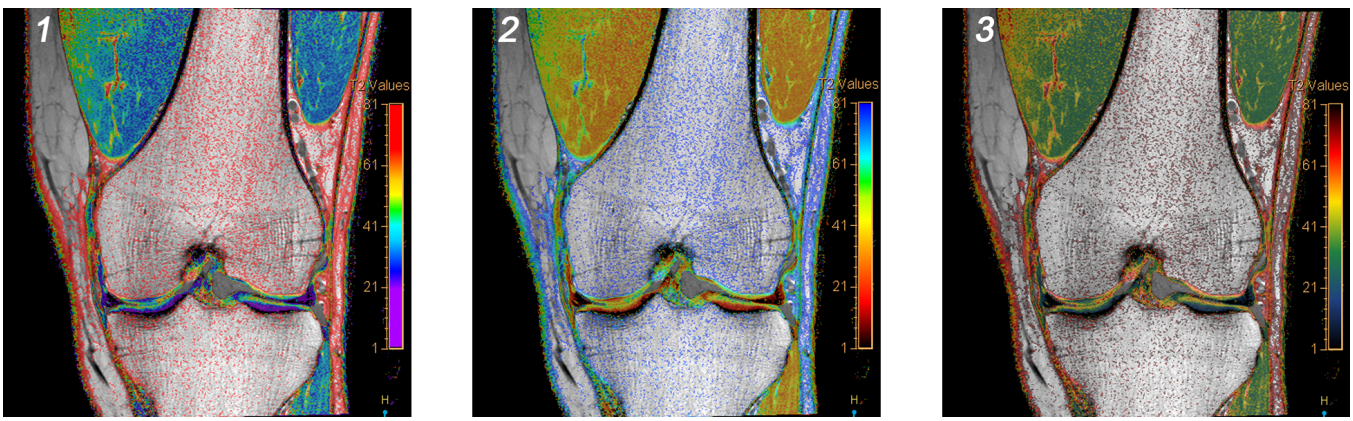

Fig. 124: Examples of the color maps. 1 - Rainbow, 2 - Reverse Rainbow, 3 - Autumn.

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Color LUT	Minimum value				Maximum value
Rainbow	Violet	Blue	Lightblue/ Green	Yellow/ Orange	Red
Reverse Rainbow	Black/Red	Orange	Yellow	Green	Blue
Autumn	Black/Blue	Green	Yellow	Orange	Red/Black

Color Range

- To select a predefined color range or to adjust the color range according to the own preferences.

  Possible settings are: '1-81', '0-100' and 'Modify Range'.

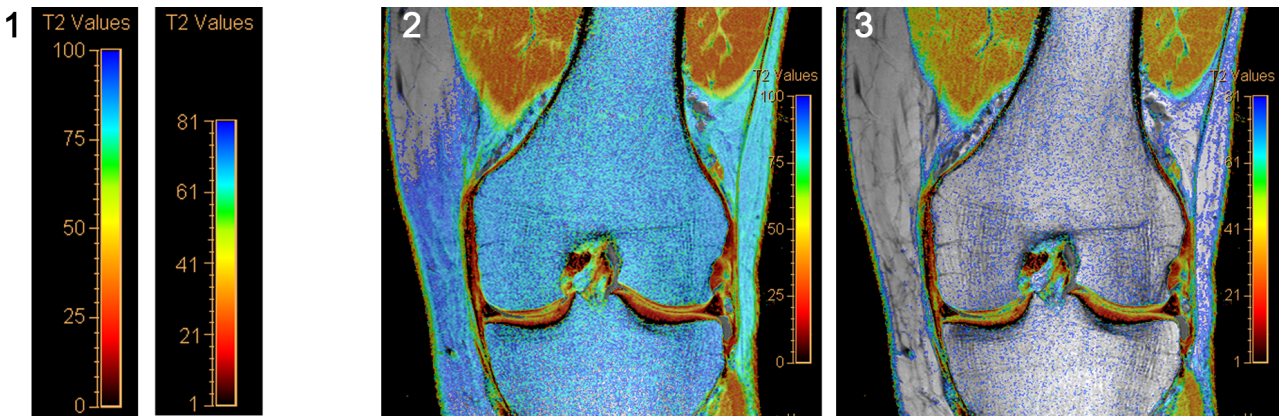

Fig. 125: 1: Color bars of 0-100 and 1-81 besides each other to visualize the effect on the color display. 2: Reversed Rainbow color map with color range 0-100 . 3: Reversed Rainbow color map with color range 1-81.

More Functions within the Cartilage Assessment package

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.

Export the results

1. Press CTRL+C to export the results as CSV file (Comma Separated Values) to the clipboard.
2. In a spreadsheet application, press CTRL+V to paste the CSV file.

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Workflow

Launch the MR Cartilage Assessment package

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

1. Select a suitable cartilage multi-echo series.

2. Click ’MR Cartilage Assessment’.

   The MR Cartilage Assessment package opens.

Scroll through images

Through echoes

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

Through slices

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

Standard Measurements

Standard ROIs can be used to quickly analyze focal lesions. For each ROI, the average relaxation time and standard deviation is calculated and displayed on screen. Additionally, it is possible to measure distances and read the pixel values. The standard measurements are available via the Common Tools panel.

1. In the Common Tools panel, click on the arrow to open the Standard Measurement drop-down menu.

   This menu offers the options:

   - Pixel value
   - Freehand
   - Rectangular
   - Ellipse
   - Distance

2. Select any of the Standard Measurements and proceed as described below.

Pixelvalue

1.  Select 'Pixel Value'.
2. Click any pixel in the source image and/or in the map.

   The pixel value for this pixel will be displayed.

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3. Click any pixel in the map.

   The calculated T2 relaxation time in milliseconds for this pixel will be displayed.

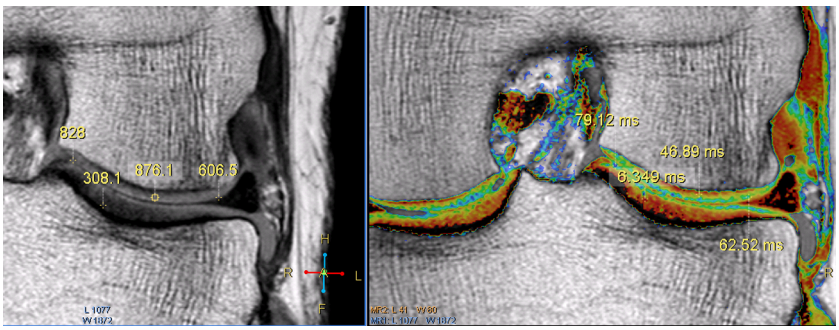

Fig. 126: Pixel value measurement. Left: on source image. Right: on map.

Freehand

1.  Click once to define one point of the ROI contour. Repeat this till the contour is completed. When finished, double-click to confirm the ROI.
2. Do this on the source image and/or on the map.

   The results will be displayed per ROI:

   - the area in mm^2
   - the mean value (pixel value on the source image and relaxation time on the map)
   - the standard deviation (pixel value on the source image and relaxation time on the map)
   - the minimum value (pixel value on the source image and relaxation time on the map)
   - the maximum value (pixel value on the source image and relaxation time on the map)

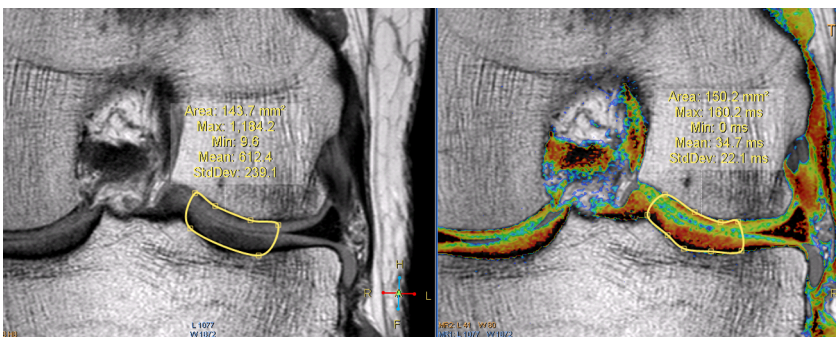

Fig. 127: Freehand measurement. Left: on source image. Right: on map.

Rectangular

1.  Click once to define the first vertex of the rectangular ROI.
2. Click again to define the second vertex.

3. Move the mouse to enlarge/reduce the immediately displayed rectangular ROI.
4. Click to confirm the opposite border and in this way the rectangular ROI.
5. Perform the previous steps on the source image and/or on the map.

   The results will be displayed:

   - the area in mm^2
   - the mean value (pixel value on the source image and relaxation time on the map)
   - the standard deviation (pixel value on the source image and relaxation time on the map)
   - the minimum value (pixel value on the source image and relaxation time on the map)
   - the maximum value (pixel value on the source image and relaxation time on the map)

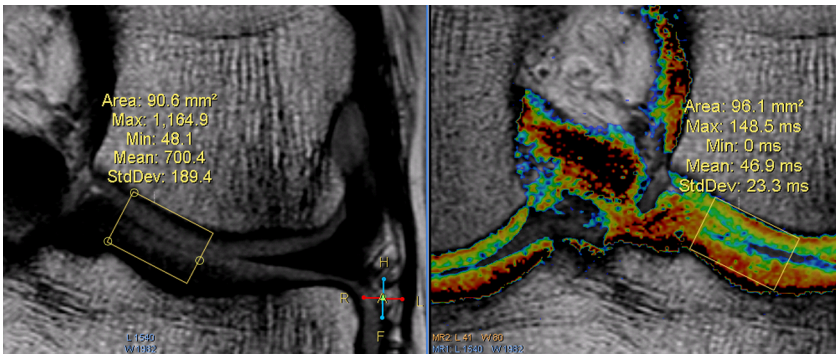

Fig. 128: Standard Measurement Rectangular on source image and on map with results. On the map the 3 anchor points (2 vertices and the 3rd one to define the opposite border) are visible.

Ellipse

1.  Click once to define the first point of the ellipse.
2. Click once more to define the width of the ellipse.
3. Move the mouse to enlarge/reduce the immediately displayed ellipse.
4. Click to confirm the ellipse.
5. Perform the previous steps on the source image and/or on the map.

   The results will be displayed:

   - the area in mm^2
   - the mean value (pixel value on the source image and relaxation time on the map)
   - the standard deviation (pixel value on the source image and relaxation time on the map)
   - the minimum value (pixel value on the source image and relaxation time on the map)
   - the maximum value (pixel value on the source image and relaxation time on the map)

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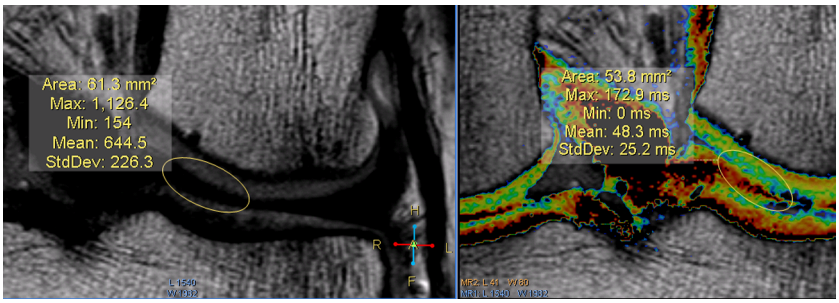

Fig. 129: Standard Measurement Ellipse on source image and on map with results. On the map the 4 anchor points (defining length and width) are visible.

Distance

1.  Click to define the first point.
2. Click to define the second point.

   The result in mm is displayed immediately.

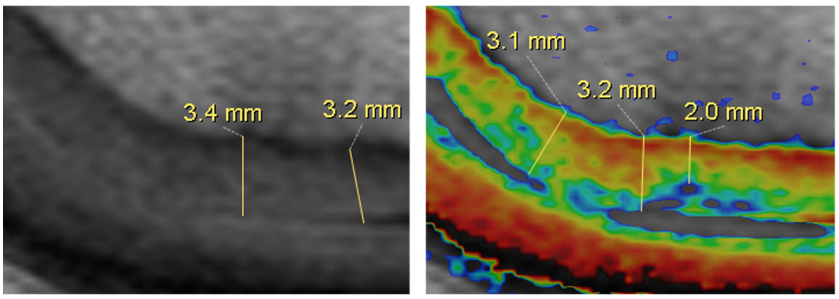

Fig. 130: Standard Measurement Distance on source image and on map.

Rectangular Layered ROI

Rectangular layered ROIs can be used to analyze focal lesions. A ROI is divided into layers. For each layer the average relaxation time is calculated. Place the first two points on the bone interface and the final point at the cartilage surface.

▷ You can draw a rectangular layered ROI on the map and on the source image.

1. Zoom the images for best cartilage visualization.
2. Optionally: drag the slider to reduce the number of layers from 3 to 1 or 2.
3.  Click 'Draw layered ROI'.
4. Click on the bone interface to define the first vertex of the rectangular layered ROI.
5. Click once more on the bone interface to define the second vertex.
6. Move the mouse to resize the immediately displayed rectangle.

7. Click to define the third anchor point on the opposite border of the ROI and in this way to confirm the ROI.

   The ROI is automatically divided in the three layers (depending on the layer slider this might also be two or one): Deep, Intermediate and Superficial, and the numerical and graphical results are displayed.

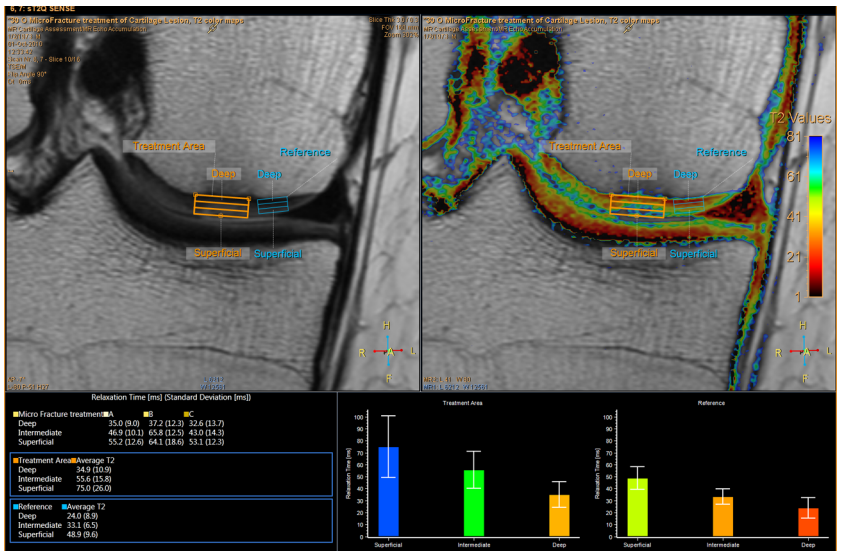

Fig. 131: Rectangular Layered ROI on map and source image with results. The 3 anchor points are visible on both images.

8. **To modify a current ROI**

   - Move the cursor over the ROI to make it current.

     The ROI lines will show up thicker and the anchor points will be displayed.
   - Then click any of the anchor points to resize or angle the ROI.
   - Click and drag in the center of the ROI to move it.

9.  **To draw multiple ROIs**

   - Click 'Draw layered ROI' to enter drawing mode again.
   - Then repeat the above mentioned steps.

Curved Layered ROI

Curved Layered ROIs can be used to analyze complete cartilage structures. A ROI is divided into layers and segments. For each cell the average relaxation time is calculated.

A ROI is defined by drawing two curves. The first curve is drawn along the bone interface, the second along the cartilage surface. Draw curves by placing multiple points and close the drawing by double-clicking the last point.

▷ You can draw a curved layered ROI on the map, on the source image and even on the map AND the source image.

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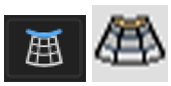
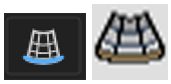
NOTICE

Entanglements are automatically disentangled.

1. Zoom the images for best cartilage visualization.
2. Optionally: drag the slider to reduce the number of layers from 3 to 1 or 2.
3. Optionally: drag the slider to reduce the number of segments from 3 to 1 or 2.
4. Optionally: reduce the opacity of the color map to better visualize the cartilage structure.
5. Optionally: select a source echo that best depicts the cartilage structure and or lesion.
6.  Click 'Draw bone interface'.
7. Click several times to define multiple points along the bone interface.
8. Double-click to confirm this contour.
9.  Click 'Draw cartilage surface'.
10. Click several times to define multiple points along the cartilage surface.

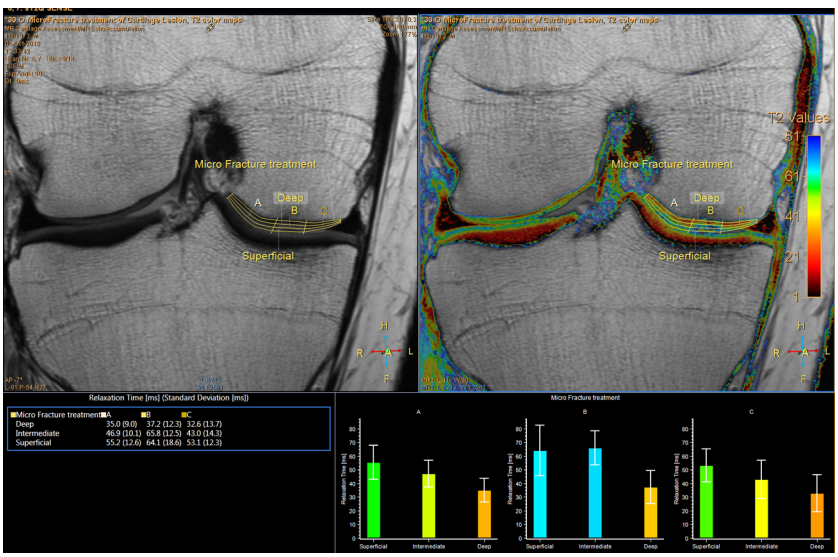
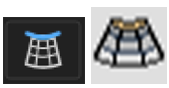


Fig. 132: A: Drawing bone interface. B: Drawing cartilage surface. The anchor points are visible for both workflow steps.

11. Double-click to confirm this contour and in such a way the ROI.

    The curved layered ROI is automatically divided into multiple cells (layers and segments).

    The numerical and graphical results are displayed immediately.
12. **To draw multiple ROIs**

    - click  'Draw bone interface' and  'Draw cartilage surface' to enter drawing mode again.

- Then repeat the above mentioned steps.

Modify a ROI (or line)

Once you've confirmed a ROI (or line), you can still adjust its shape, its position and rename or delete it.

Adjust ROI shape and position

1. Click on an anchor point and drag to adjust the ROI shape.
2. Click between anchor points and drag to adjust the ROI position.
3. Press and hold 'Ctrl' while clicking between anchor points to add an anchor point.

Rename a ROI

1. Double-click the name (by default ROI1, ROI2, ROI3 etc).
2. Delete characters where needed and type the new name.

- It is advised to rename the ROIs for easier identification (e.g. lesion, healthy). It might be helpful to add the slice number to the name so that navigation to the respective ROI is facilitated.

Delete a ROI

1. Move the cursor over the ROI to make it current.
2. Right-click on the ROI and select ’Delete’.

Optimize Color Overlay

The presentation of the color maps can be customized by limiting color display to relevant areas and by adjusting the color opacity.

1. Click the checkbox in the task guidance to enable (or disable) 'Suppress Colors outside ROIs'.

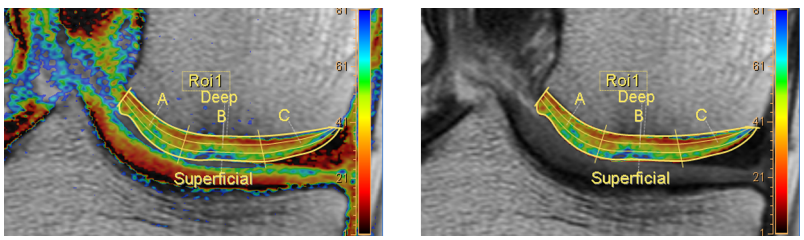
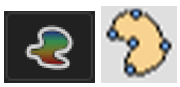


Fig. 133: Left: No suppression of colors outside ROIs. Right: Suppressed colors outside ROIs.

2.  Click 'Draw color cut-out region' to enter drawing mode.
3. Click several times to define a color cut-out ROI.
4. Double-click to close and confirm the ROI.

   Colored areas outside the ROI will be displayed without color overlay immediately.

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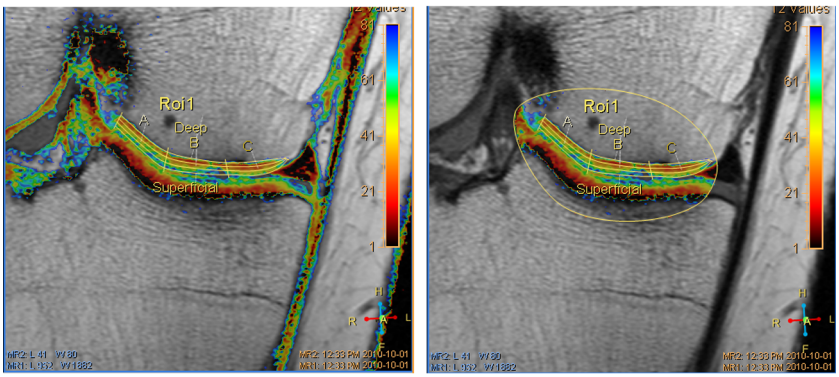

Fig. 134: Left: No cut-out ROI. The colors outside the ROI are not yet suppressed. Right: Cut-out ROI drawn and colors outside the ROI are suppressed.

Generate Series

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

1. Click 'Generate Series'.
2. Enter the name of the new imaging series.

NOTICE

Once maps are generated via 'Generate series', these maps behave differently when viewing them.

Generated Maps cannot be used anymore for measurements. ROIs are not displayed. If a cut-out ROI is drawn to supress colors outside, the outline of that ROI will be supressed.

NOTICE

Newly generated series can easily be compared in the Viewer.

Results

The package calculates the T2 relaxation times per voxel (using Ratio Least Squares method) and presents them as:

- parametric Cartilage Assessment map
- as numerical results in a table
- as graphical results in a bar chart display.

Parametric Cartilage Assessment map

The parametric color overlay represents the values of the T2 relaxation times per voxel.

In the parametric map, each color stands for a specific value/range of the T2 relaxation time. The vertical color bar serves to decode the color values into relaxation times. Different color maps can be used which also influence the display of the bar chart.

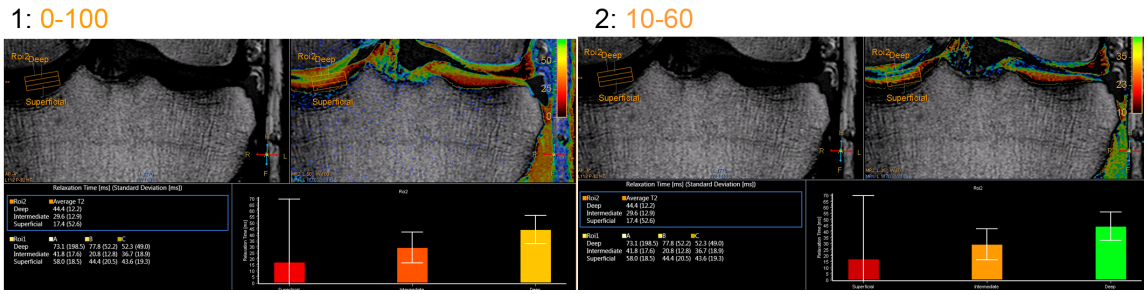

Fig. 135: Comparison of results display with different color ranges: 1 - Reverse Rainbow color map with 0-100 color range, 2 - Reverse Rainbow color map with 10-60 range.

Numerical results and graphical results

The calculation of the numerical and graphical results is based on the segments and layers of the ROIs.

The rectangular and curved ROIs are both automatically divided in three layers: Deep, Intermediate and Superficial. Furthermore the curved ROIs are divided in the segments A, B and C (from left to right).

- The table lists the calculated T2 relaxation times with standard deviation for each layer and segment.
- The graphical results in the diagram plot the T2 relaxation time (in milliseconds) versus the relative cartilage depth.

  The white lines at the upper part of each bar indicate the standard deviation.

The numerical results in the table and the graphical results use the same colors as for the ROIs so that they can easily be recognized.

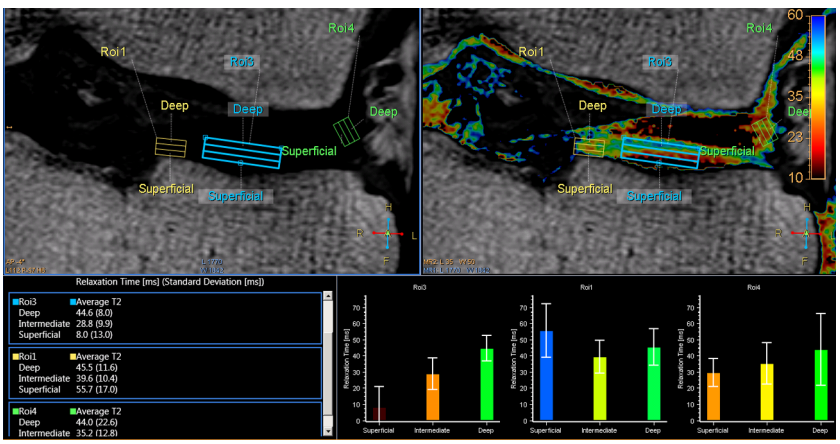

Fig. 136: Results with rectangular ROIs (Average T2 values per layer).

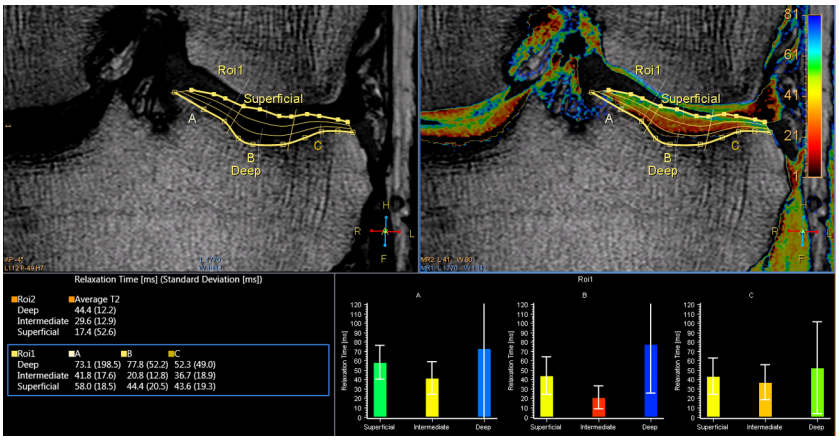

Fig. 137: Results with curved ROIs (Average T2 values per layer and segment).

NOTICE

Graphical results are only shown for the ROIs on the current slice.

The numerical results of all ROIs are however displayed in the table.

Display the slice of any drawn ROI

1. Click on a ROI name in the table.

   The display will automatically be changed and the slice will be shown with the ROI that has been double-clicked before.