5 MR Diffusion

This postprocessing package is meant to evaluate Diffusion studies and generate parametric maps.

The process of diffusion of water molecules through tissue can be measured using MRI Diffusion imaging.

Valid imaging series

A valid imaging series for the Diffusion package is a Diffusion weighted series containing multiple b-values.

NOTICE

To calculate the Apparent Diffusion Coefficient (ADC map), diffusion weighted images acquired using at least 2 different b-values are needed.

NOTICE

Anisotropy maps (FA or Directional FA) need an acquisition with at least 6 different diffusion directions in addition to a diffusion weighting (b=0).

300006338791_A/881 * 2021-06-30

Indications for Use

The MR Diffusion application is designed to assist in evaluation of MR Diffusion Weighted Imaging (DWI) and Diffusion Tensor Imaging (DTI) data to analyze diffusion and anisotropic properties of tissue.

User Interface

Screen layout

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

- Source image in the middle of the imaging volume.
- In real-time calculated Parametric Diffusion maps.

Task Guidance

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

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

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:

- 1x1.
- 2x2.

Select b-values

Use this function to select at least 2 b-values for processing.

Advanced Diffusion Tensor Maps

Select this option to allow additional maps to be selected in the **Diffusion Tensor Maps** section of the task guidance panel. The following advanced diffusion tensor maps are available:

- Axial Diffusivity
- Radial Diffusivity
- Relative Anisotropy

Register Data While Saving

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

3000063387791_A/881 * 2021-06-30

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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.

NOTICE

The newly generated registered series can be recognized by the prefix 'Reg' in Series description.

Mask

Once enabled, this function displays the mask on the source image(s).

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 Diffusion 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.

3000063879l_A/881 * 2021-06-30

Workflow

Launch the MR Diffusion package

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

1. Select a suitable diffusion series.
2. Click ’MR Diffusion’.

The MR Diffusion package opens.

Scroll through images

Through slices (or resulting) maps

1. In the image (or map) viewport, drag up- or downwards.
2. Alternatively use the up and down arrow keys.

Through b-values

1. In the image viewport, drag to the left or to the right.
2. Alternatively use the left and right arrow keys.

Select the Desired Maps

In the task guidance panel you can select the maps 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.

NOTICE

Depending on the imaging parameters, not all types of parametric maps might be available.

Parametric maps that cannot be calculated with a specific dataset are grayed out, and a message is displayed in the bottom line of the view ports.

NOTICE

The preview of ADC, EADC and DWI iso maps is not available; however they can be generated and reviewed.

Define the Mask

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

3000063387 91_A/881 * 2021-06-30

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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 and will be excluded from the calculation. Only pixels with intensity above the mask value are used for the calculations.

1. Drag the slider to define the mask.

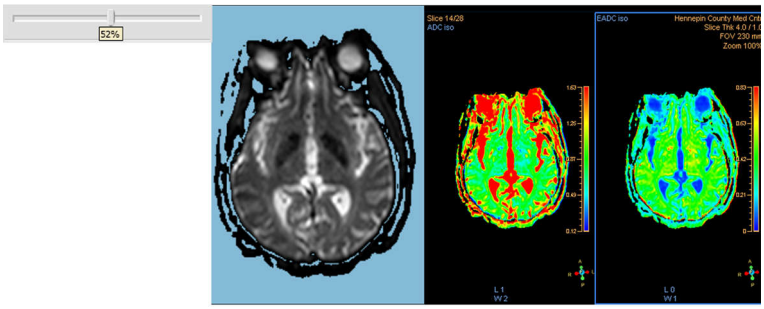

Fig. 34: The mask is overlaid to the current source image.

Alternatively:

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

Generate Maps

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.

Parametric Maps

The results will be provided as parametric maps. The type of the map is indicated in the map's series type field.

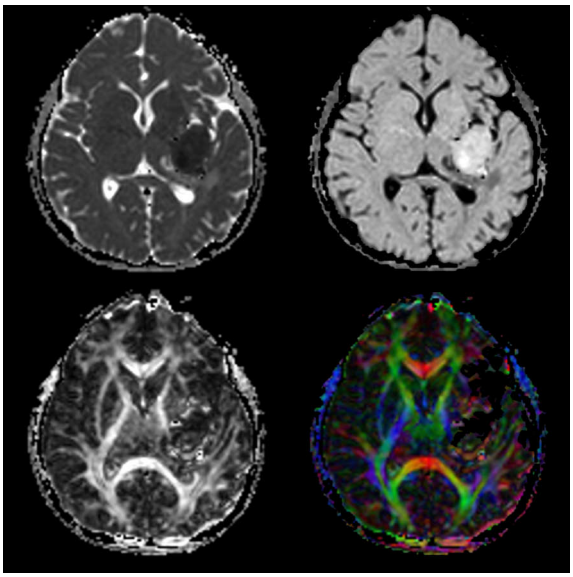

Fig. 35: Examples of maps. Clockwise from upper left: ADC map, eADC map, FA direction map, FA map

Scrolling through the maps shows which types of maps are available for the current series (not all types of maps are suitable for every type of diffusion series).

If an ADC iso and eADC iso map are available, directional ADC and directional eADC maps can also be generated (even though they are not available in the preview).

DWI iso

The DWI iso map is calculated by first finding the net ADC from all of the available gradient directions.

This net ADC is then used together with the b=0 image to create the DWI iso map. Since this uses all available directions, the SNR of the DWI iso map is improved especially with DTI series.

- The DWI iso images show a better image quality when the number of diffusion directions increases. The DWI iso images will have less noise. There is an increase in signal when more than 16 directions are acquired. The higher signal gives a sharper appearance.
- The option to create DWI iso images is not available for diffusion series that are acquired with gradient overplus as the P_oblique, M_oblique and S_oblique directions are not saved in the database. The DWI iso option is also only available when 2 b values are selected.

ADC and ADC iso

The Apparent Diffusion Coefficient (ADC) identifies the average diffusion as measured by the diffusion imaging sequence.

The ADC is given in 'mm^2/s' and can be expected to have an order of magnitude of 0.6 to 1.0 x 10^{-3} mm^2/s for a tissue like white matter.

The ADC can be obtained for each separate diffusion direction (identified as 'ADC') but also the average or isotropic ADC (ADC iso) can be obtained when enough non-colinear diffusion directions were acquired.

3000063387 91_A/881 * 2021-06-30

Tissue characteristics	Signal DW images	Signal ADC maps	Signal eADC maps
High ADC (rapid diffusion)	hypointense, more signal attenuation	High signal intensity	Low signal intensity
Low ADC (slow diffusion)	hyperintense, less signal attenuation	Low signal intensity	High signal intensity

Tab. 1: Signal in ADC and eADC maps

ADC maps provide anisotropic information and are available for each diffusion direction: S, M, P.

eADC and eADC iso

The exponential-ADC or eADC is used to show the diffusion weighting effect of a tissue. The eADC is calculated as exp(-b*ADC). In the eADC maps, CSF has very low signal so that subtle periventricular (e)ADC differences are more easily noticed.

FA (Fractional Anisotropy) map

Fractional anisotropy (FA) maps can be calculated from the DTI information. The FA values indicate the degree of anisotropy and range from 0 to 1. In case of no anisotropy (or normal isotropic diffusion, e.g. in grey matter tissue) the FA equals 0. For most white matter regions the FA value is much higher (for example, in the corpus callosum the FA value is around 0.6).

At least six different diffusion directions are needed to uniquely describe the diffusion pattern and to calculate the diffusion tensor matrix per pixel. From this calculation, the fractional anisotropy can be displayed in a FA map. High signal intensity corresponds to high fractional anisotropy and low signal intensity to low anisotropy.

Two different types of FA map are available: FA greyscale map (also referred to as FA map) and FA direction map.

FA (greyscale) map

Directional information is not provided.

FA Direction map

The color indicates the most important diffusion direction of a voxel:

- Blue for FH-direction.
- Red for RL-direction.
- Green for AP-direction.

3000063879l_A/881 * 2021-06-30

Advanced Diffusion Tensor Maps

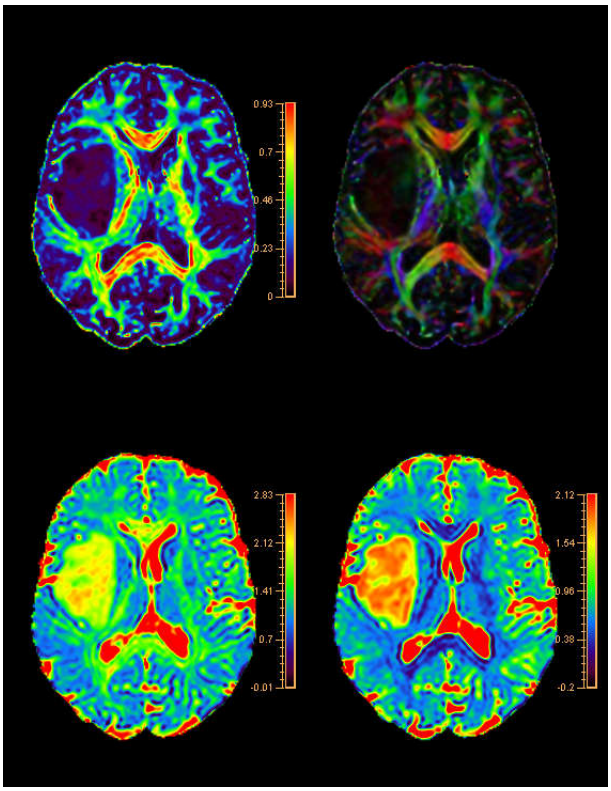

Fig. 36: Clockwise from upper left: FA, FA direction, Axial Diffusivity, Radial Diffusivity

Axial Diffusivity

The Axial Diffusivity map displays diffusivity along the principal axis. It is also called the longitudinal diffusivity or the parallel diffusivity. It is associated with neuro-degenerative diseases.

Radial Diffusivity

The diffusivities in the two minor axes are often averaged to produce a measure of radial diffusivity: $\lambda_\perp = (\lambda_2 + \lambda_3)/2.$

This quantity is an assessment of the degree of restriction due to membranes and other effects, and proves to be a sensitive measure of degenerative pathology in some neurological conditions. Radial diffusivity is used as a measure of myelin of white matter. It is also called the perpendicular diffusivity.

Relative Anisotropy (RA)

The RA maps appears very similar to the FA map. However, the RA map uses a slightly different calculation: $RA = \sqrt{\left((\lambda_1 - \overline{\lambda})^2 + (\lambda_2 - \overline{\lambda})^2 + (\lambda_3 - \overline{\lambda})^2\right)/3\overline{\lambda}}$

300006338791_A/881 * 2021-06-30