New 'ADC & b-value' Tool in *syngo*.via

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Introduction

Diffusion-weighted imaging (DWI) is a key sequence in MRI, especially in the area of oncology imaging as it reveals the microscopic tissue architecture. High b-value images in particular deliver the most valuable clinical information, but they require long acquisition time and are often prone to distortion and ghosting artifacts.

The new *syngo*.via VB10 software allows you to generate ADC maps and computed b-value images from acquired DWI series. This can save valuable scan time while providing images of overall better accuracy [1].

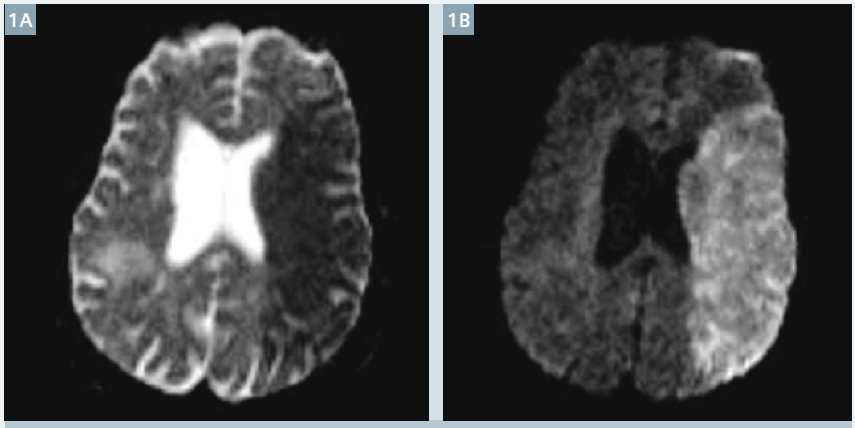
Additionally, with the Auto Preview functionality, the optimal b-value maximizing the contrast to better fit the pathology, the body region and the patient, can be simulated in real time.

Methodology

Background

The diffusion coefficient is a measure of the mobility of molecules within their environment.

In MRI, the ADC (apparent diffusion coefficient) is used: ADC maps show parametric images of the apparent diffusion coefficient of diffusion-weighted images.



1 ADC map **(1A)** and diffusion-weighted image **(1B)** show reduced diffusion in the left brain. *Reproduced with permission from: Praxiskurs MRT, Anleitung zur MRT Physik über klinische Bildbeispiele, W. Nitz.*

On ADC maps, a dark voxel represents a voxel with low ADC and low diffusion. In the diffusion-weighted images, it is the opposite, and low diffusion regions are represented by bright voxels (Fig. 1).

The evolution of the signal intensity in DWI images is described by an exponential function and is related to the b-value parameter of the sequence. This correlation is described by the formula:

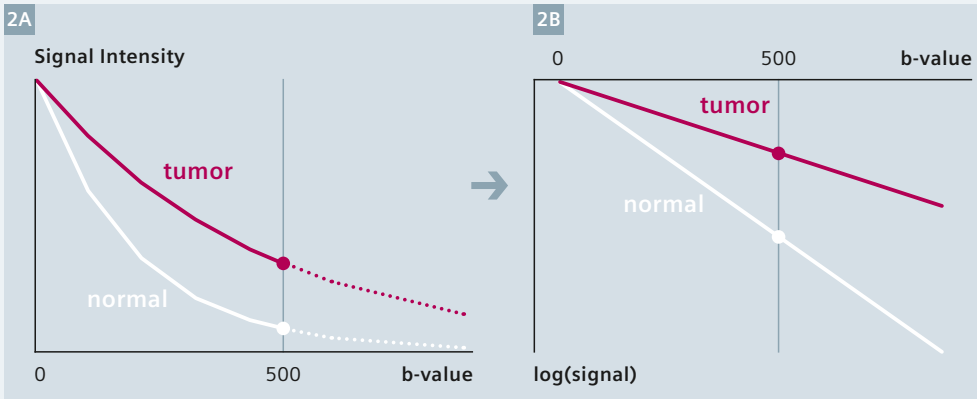
$$I(x,y) = \exp[-b \cdot D(x,y)]$$

where I is the signal intensity, b the b-value, and D the ADC coefficient.

A fitted linear regression model can be used to calculate the diffusion coefficient D for each voxel, as illustrated in Figure 2.

Consequently, with at least two b-values acquired, it is possible to compute the ADC for each voxel. Additionally, due to the linear correlation, it is then possible to extrapolate and generate DWI images of any other b-value.

The ADC map and computed b-value images can be generated 'inline' on the acquisition workplace of Siemens MR systems, making them immediately available for reading. This is an



2 Illustration of the signal intensity evolution in function of the b-value: exponential correlation for the signal intensity itself **(2A)**, linear correlation for the logarithm **(2B)**.

obvious advantage in terms of clinical workflow.

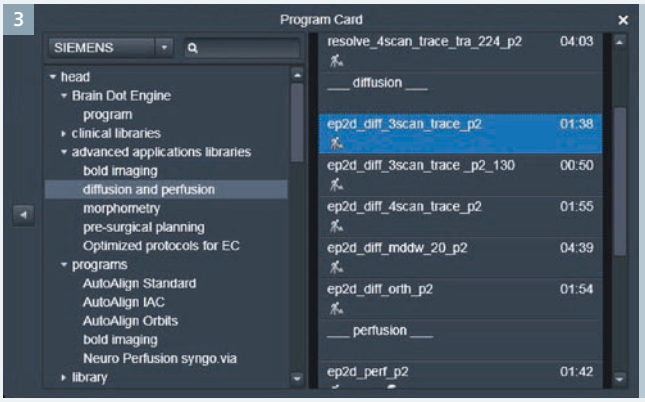
In some cases, the offline computation of the ADC maps can be beneficial, e.g. in case low b-value images have to be excluded from the map generation in order to reduce perfusion effects.

The offline and interactive approach is especially interesting for the gener-ation of computed b-value images. For example, there might be the need to compare with prior exams that have been acquired with a different protocol and different b-values. Additionally, the interactive aspect makes it possible to evaluate, in real-time, the signal evolution with different diffusion weighting, and find the b-value which best maximizes the contrast between the lesion and the surrounding tissue. This is adding an additional degree of freedom over the choice of the b-value [2].

Input series

The input series are diffusion-weighted images (trace-weighted images) acquired with a minimum of two different b-values. The maximum number of b-values is only limited by the scanning protocol. The typical diffusion sequence can be found in the program card of the Siemens protocol tree for the corresponding body region, as illustrated in Figure 3 for a head examination. The RESOLVE sequence (EPI segmented in the read-out direction), which reduces susceptibility and blurring artifacts, is compatible with the ADC & b-value tool.

Distortion corrected and filtered images can also be used, as long as the filter criterion is the same across all b-values.



3 Typical diffusion sequence for head examinations.

Tool activation and selection of the input series

The ADC & b-value tool is available in the lower right corner menu under 'Arithmetic Tools' as illustrated in Figure 4. This triggers the opening of the ADC & b-value card as a floating window (Fig. 5).

If the segment where the tool is activated already contains diffusion data, it is recognized and automatically loaded as input series. If the tool is activated in a segment which does not contain diffusion data, the input series can be selected via drag & drop from the series navigator.

As previously mentioned, the input series must have been acquired with a minimum of two b-values. If a series with less than two b-values is selected (or a non-diffusion series), the calculation cannot be performed.

The second b-value can be dropped afterwards with drag & drop into the input section.

The entire data in the input section can be replaced with new data from the series navigator and segment by holding the 'shift' key.

4 Activation of the ADC & b-value tool.

5 ADC & b-value card.

Computing ADC maps and extrapolated b-value images
The ADC & b-value card is divided into two sections: an upper part for the calculation of the ADC map, and a lower part for the generation of computed b-value images.

The typical sequence to generate ADC maps and computed b-value images is the following:

1. Select in the 'input series' section the b-value images to include in the calculation (Fig. 6):
   - Use the checkbox to select the b-value images to be included.
   - Use the 'Minus' icon to selectively delete single b-value images from this section.
2. Select the threshold for the ADC map calculation.

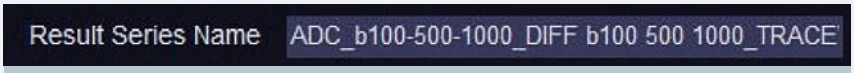
   The threshold is a parameter to reduce the noise in the resulting images. It is configurable and works as follow: For a specific voxel, if the signal intensity on the acquired b-value images selected for the calculation drops under the configurable threshold, its value is set to NULL and will be represented by a dark voxel in the ADC map. The configurable threshold has a value range of 0-1000 and is set by default to 10.
3. Check the name of the resulting series.

   After selection of the b-value images to include in the calculation, the default result series name is displayed in the 'Result Series Name' section (Fig. 7)

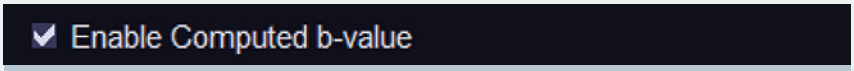
   The name is based on 'ADC_' and the information about the selected b-value images, plus the series description. The name can be modified.
4. Enable the computed b-value images.

   The b-value images option can be switched on by clicking the 'Enable Computed b-value' check box (Fig. 8). If you do not wish to generate these images (but only ADC), the box should stay unchecked.

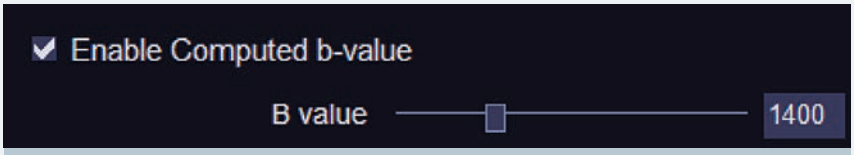
6 Selection of the b-value images.



7 Result Series Name.



8 'Enable Computed b-value' checkbox.



9 Slider bar or manual entry for b-value generation.

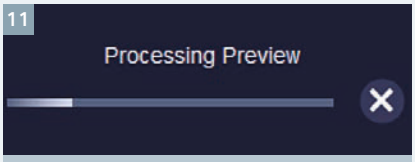
10 Selection of the target segments (here in a dual monitor setup). The orange arrow represents a potential drag & drop interaction by the user to modify the target segment of the computed b-value image.

5. Select the desired b-value for the computed image.

   The computed b-value images can be generated for b-values between 0 and 5000. The desired value can be selected by moving the slider bar or by typing in the value (Fig. 9).

   The result series name for the computed b-value is set per default by the system. The name is based on 'Calc_' plus the information about the desired b-value and the b-value images used as input (e.g. b1400_b50_400_800) plus the series description (e.g. ep2d_diff_tra_b50_400_TRACEW). The name can be modified.
6. Select the target segments and generate preview images.

   In the lower part of the card, the target segment is displayed. It represents the current layout setting (including dual monitor if appropriate) and the default position where the ADC map and the computed b-value image will be loaded. These positions can be modified by dragging & dropping the ADC and b-value icons to another segment (Fig. 10).



11 Progress bar.

12 Auto Preview functionality. The slider bar triggers a real-time update of the computed b-value image between b0 and b5000.

Clicking the 'Preview' button at the bottom of the card generates a preview of the ADC map and computed b-value series. The results are not stored when using the preview functionality.

During the calculation, a progress bar is displayed (Fig. 11). The computation can be canceled with the 'cancel' button.

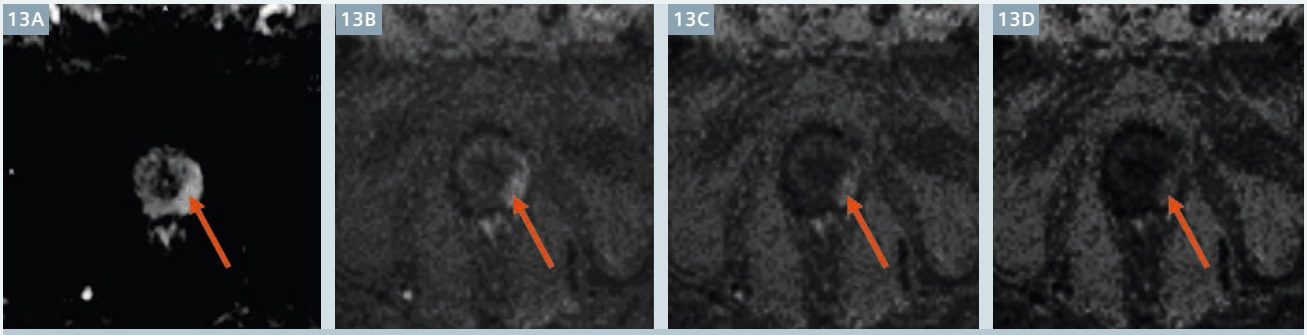
7. For interactive and real-time generation of computed b-value images, activate the 'Auto Preview' functionality (Fig. 12).

   Next to the b-value slider, the 'Auto Preview' check box can be activated. By moving the slider, the corresponding computed b-value image in the target segment is generated and updated in real-time. Thus, the influence of the b-value on the signal intensity can be seen interactively which may help to carve out specific lesions (cf. paragraph 'clinical cases').

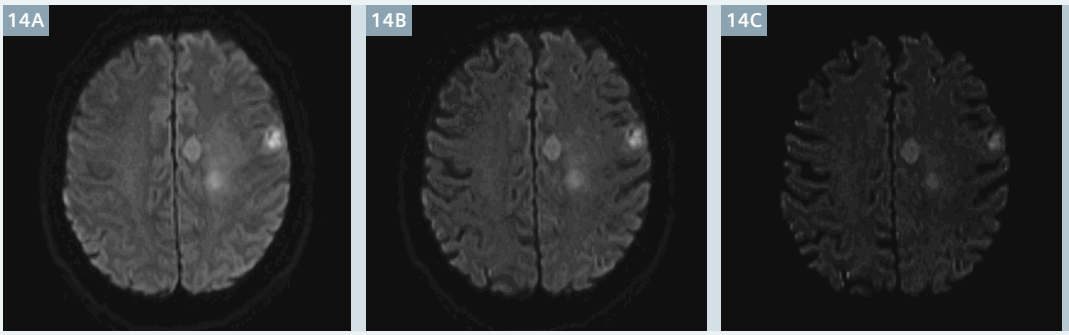
8. Save the results.

   When completing the case, click 'OK' to store the results in the series navigator and permanently save them with the patient data.

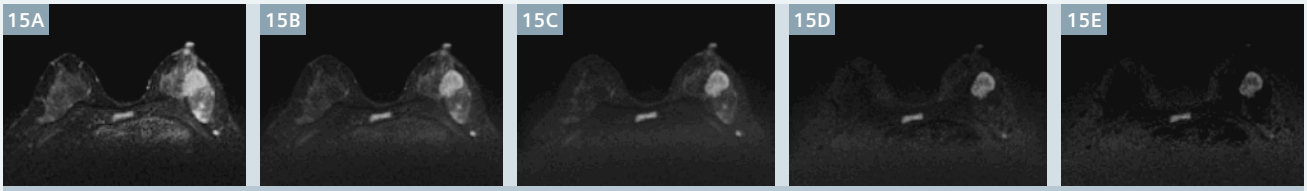
Clinical examples



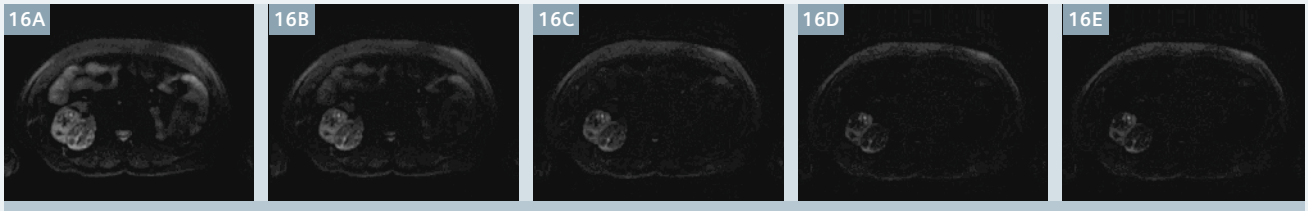
13 67-year-old man with prostate cancer. Acquired b800 **(13A)** and computed b1600 **(13B)**, b2000 **(13C)**, b2500 **(13D)** images.



14 58-year-old man with multiple brain lesions. Acquired b1000 **(14A)** and computed b1400 **(14B)**, b2200 **(14C)**.



15 41-year-old woman with breast tumor. Computed b500 **(15A)**, b800 **(15B)**, b1000 **(15C)**, b1400 **(15D)**, b1800 **(15E)** images show signal evolution in the lesion. Series are computed from RESOLVE diffusion series acquired with b0, b500, b1000.



16 62-year-old male patient with kidney tumor. Computed b600 **(16A)**, b800 **(16B)**, b1000 **(16C)**, b1200 **(16D)**, b1400 **(16E)** images show signal evolution in the kidney. Series are computed from standard diffusion series acquired with b50, b800.

Summary

This article describes the feature 'ADC & computed b-value' available in *syngo*.via VB10. This new tool provides an increased degree of freedom in the choice of the b-value for disease detection and characterization. This algorithm has been shown to save scan time and increase diffusion image quality. Easy to use and flexible with the Auto Preview functionality, it is standard with the *syngo*.MR General Engine and therefore included in the upgrade to *syngo*.via VB10.

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References

1 Feasibility study of computed vs measured high b-value (1400 s/mm²) diffusion-weighted MR images of the prostate, World J Radiol 2014 June 28; 6(6): 374-380.

2 Blackledge MD, Leach MO, Collins DJ, Koh DM. Computed diffusion-weighted MR imaging may improve tumor detection. Radiology 2011; 261: 573-581.

3 Source of brain image (first paragraph): Praxiskurs MRT, Anleitung zur MRT Physik über klinische Bildbeispiele, W.Nitz.

4 Rosenkrantz, et al. Computed diffusion-weighted imaging of the prostate at 3T: impact on image quality and tumour detection. European Radiology 2013; 23: 3170-7c.