

# Improved lesion visualization using B-value maps based on thresholded DWI images

Peter Gall<sup>1</sup>, Rakesh Kasibhatla<sup>2</sup>, and Heiko Meyer<sup>1</sup>

<sup>1</sup>Siemens AG, Healthcare Sector, Erlangen, Germany, <sup>2</sup>Siemens Technology and Services Pvt Ltd, India

## Introduction

Diffusion weighted imaging (DWI) is one of the most popular functional imaging methods in MRI. A particular interest in DWI lies in the efficient identification of dense tissues that often indicate tumor lesions. The density of tissue can be quantified by assessing the diffusivity of water. The simplest measure for the diffusivity is the apparent diffusion coefficient (ADC). The ADC can be determined by the acquisition of two or more images at different diffusion sensitizing gradients, characterized by the b-value. With increasing b-value, the signal in the corresponding images decreases. For the sake of simplicity the decrease is assumed to be modeled well by a mono-exponential decay:  $S(b) = S_0 \cdot \exp(-b \cdot \text{ADC})$ , however the result of the abstract holds for more complex models (e.g. IVIM) too. The quantitative nature of ADC is a very attractive feature of DWI. However, the corresponding maps show a negative contrast in dense tissues. In clinical practice it is therefore often only used as a secondary image. For visual lesion screening very often images with high b-values are used as they show a positive contrast in dense tissues. However the b-values at which those tissues show up at best contrast strongly depends on the lesion. Typically images at very high values (1000 - 2000 s/mm<sup>2</sup>) show the desired contrast. Those images however also suffer from very low signal to noise ratio and therefore have very little contribution to the determination of ADC. For the determination of ADC typically b-values between (50-1000 s/mm<sup>2</sup>) are acquired where the contrast for lesion screening is not satisfying. For this reason synthetical images are created from the acquired images by using a signal model, whose parameters are determined in the acquired b-value range. Such approaches have proven to be very useful in clinical reading ([1], [2]). Ideally the extrapolation would be interactive such that the radiologist can look at images with the desired lesion contrast. However such tools are only available in research settings. In this work we suggest to compute a new map whose intensities indicate the b-value at which the diffusion signal drops under a given threshold. Using this map, the image impression of any high b-value image can be achieved just by windowing, a function which is available on any simple image viewing workstation.

## Methods

In order to illustrate the technique two exemplary volunteers that gave informed consent underwent DWI.

One scan was performed on a 3T Magnetom Prisma system (Siemens AG, Erlangen) on a patient with known prostate cancer using a 2D RF (zoomed) EPI technique at TE = 60 ms and TR = 3000 ms. The b-values were chosen to be 50, 400 and 800 where 4, 7 and 13 averages were taken at the 3 b-values. The field of view was chosen to be 100x100 mm at an in-plane resolution of 64x64 pixels and 20 slices were acquired at a slice thickness of 3.5 mm. The signal was modeled to be  $S(b) = S_0 \cdot \exp(-b \cdot \text{ADC})$ .

Another scan was performed on a 1.5T Magnetom Avanto system (Siemens AG, Erlangen) on a volunteer using an EPI sequence at TE = 69 ms and TR = 3500 ms. 7 b-values were acquired (0, 50, 100, 300, 600, 900 and 1050), where the b=0 image was omitted for this evaluation. 20 slices at a thickness 5 mm were acquired with an in-plane field of view of 309x380 mm at an in-plane resolution of 208x256.

The threshold was defined to be 10 (a.u.) for both cases. The b-value at which the signal drops under the threshold (thr) can then be found from:  $b_{\text{thr}} = -1/\text{ADC} \cdot \log(\text{thr}/S_0)$ . The evaluation was performed for each voxel and the resulting b-values at which the signal model predicted the drop under the given threshold was stored in a map. The methods were implemented in C++ and the results were visualized using the Extensible Imaging Platform (XIP), Siemens Corporate Research, Princeton US. In addition to the b-value map also the ADC maps were computed along with an extrapolated image for a very high b-value of 2000.

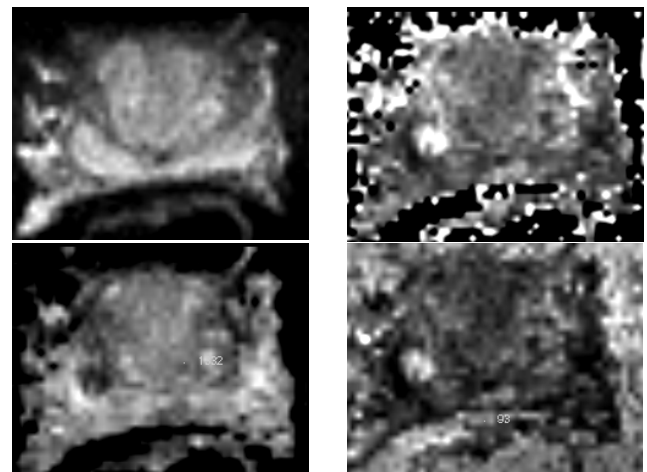


Fig 1. Prostate: Upper left: Image at b800, upper right: b-value map, lower left ADC map, lower right: computed image for b=2000

## Results

Fig. 1 shows the effect of the evaluation for the prostate. The lesion on the lower left of the prostate is not clearly visible on the image acquired at b800. It becomes apparent as dark spot in the ADC image. The b-value map proposed here has a high positive contrast that is similar to the extrapolated b-value image.

Fig. 2 shows the effect of the evaluation for the pelvis. The bones are clearly highlighted in the b-value map at a positive contrast.

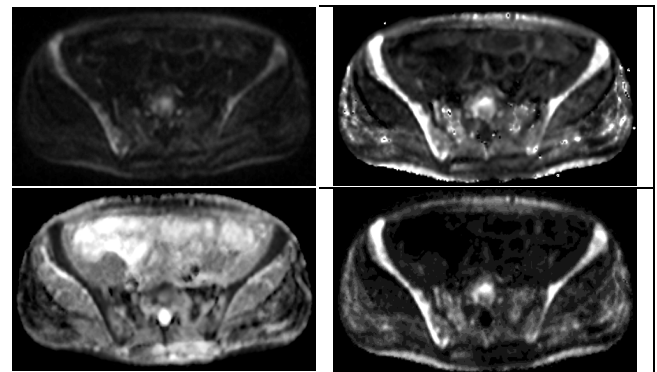


Fig 2. Bones: Upper left: Image at b800, upper right: b-value map, lower left ADC map, lower right: computed image for b=2000

## Discussion and Conclusion

The proposed method allows to provide a pre-computed map that enables the radiologist to interactively achieve the image impression of a high b-value map by manipulating the window width and center of the visualization of the image. This tool is available on any reading station and does not require advanced tools. The utility of artificial computed high b-value images has proven its added clinical value for lesion detection. Furthermore the maps have the potential to serve as a basis new segmentation methods basing on DWI.

## Acknowledgment

We would like to thank Dr. Koh from the Royal Marsden Hospital in Sutton UK for providing us with data for the exploration of this method.

## References

1. Maas, Marnix C., Jurgen J. Fütterer, and Tom WJ Scheenen. "Quantitative Evaluation of Computed High b Value Diffusion-Weighted Magnetic Resonance Imaging of the Prostate." *Investigative radiology* 48.11 (2013): 779-786.
2. Rosenkrantz, Andrew B., et al. "Computed diffusion-weighted imaging of the prostate at 3 T: impact on image quality and tumour detection." *European Radiology* (2013): 1-8.