The Use of Quantitative T2 to Enhance Computed Diffusion Weighted Imaging

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Introduction: Diffusion weighted magnetic resonance (DW-MR) imaging in the body is being increasingly used for tumour detection based on its high contrast between lesion and normal tissue [1]. A study [2] has shown the added value of computed diffusion-weighted MR Imaging (cDWI) in improving image contrast by synthesising higher-b-value DW images from images acquired at lower b-values. However, this method is still influenced by T2 contrast, and regions of disease with reduced or long T2 relaxation times may confound interpretation. The purpose of this study is to describe a modified cDWI model that provides synthetic images at arbitrary b-values and echo-times, which can be used to remove or increase the T2 contrast from the synthesised diffusion images by using additional T2-weighted acquisitions from the same DWI acquisition protocol. We investigate the feasibility of this method to improve image contrast and tumour detection.

Methods: *Imaging:* Nine cancer patients (four malignant pleural mesothelioma, four primary prostate cancer, one bone metastasis in a patient with metastatic prostate cancer) underwent DW-MR Imaging on a 1.5/ 3 T clinical scanner (Avanto/ Aera/ Skyra, Siemens AG, Healthcare, Erlangen, Germany). Several different diffusion protocols were employed, each acquiring three b values: (100, 500, 800 s/mm^2), (50, 400, 900 s/mm^2), (50, 600, 900 s/mm^2), which reflect the clinical imaging protocols employed at our institution. The T2 weighted scans used the same diffusion sequence (all with b-value 0s/mm^2), with TR as that used in the diffusion scan and 4 additional acquisitions using echo times (TE) (53-153 ms), from which a T2 map was generated. Using the same DWI imaging protocol ensured that geometry and B0 related distortion were inherently matched. Both the T2 weighted (T2w) and DWI measurements were acquired with multiple averaging to average over motion; no motion control was employed in these studies.

Processing: Images were synthesized following the modified cDWI model $S(b_c, TE_c) = S_0 \cdot \exp(-TE_c/T2) \cdot \exp(-b_c \cdot ADC)$, where S_0, T2, and ADC are estimated from joint modelling of the diffusion- and T2-weighted images. Estimation of imaging parameters and synthetic images was achieved using an in-house developed plugin for OsiriX (Pixmeo, Geneva, Switzerland), which allows the user to compute images at any b_c (0-5000 s/mm^2) and TE_c (0-300 ms) in real-time, providing a clinical tool to independently vary the T2 and diffusion image contrast.

Verification: Phantom verification was performed on a water phantom to verify the accuracy of estimating T2 from diffusion scans. The accuracy was 97% compared with T2 derived from the conventional multiple spin echo sequence.

Results:

Mesothelioma:

Figure 1 shows a series of cDWI images of a mesothelioma patient acquired using various b values (s/mm^2) and TE (ms). A short TE was simulated for the cDWI images on the first row. A solid tumour (red arrow) and the pleural effusion (blue arrow) are both bright on the T2w image and low b-value cDWI images. As b value increases, there is a noted decrease of the SNR of the fluid (blue arrow), and an obvious improvement in the image contrast between solid tumour and fluid, thus it has the potential to segment solid and fluid component of mesothelioma. Repeating the evaluation but with a TE value similar to the clinical protocol (images on the second row) resulted in lower SNR and poorer contrast between tumour and fluid.
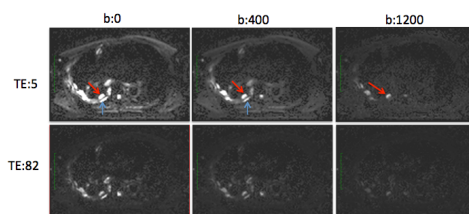

Figure 1: cDWI images of a mesothelioma patient

Bone metastasis:

Tumour heterogeneity post treatment represents a challenge for tumour delineation. The traditional method of delineating tumour on the high-b-value images is hindered by poor contrast between normal bone and metastatic disease and the presence of T2 shine through. Figure 2 illustrates the advantage of a high b value and low TE in delineating tumour (red arrow) without contamination from the area with T2 shine through (blue arrow).
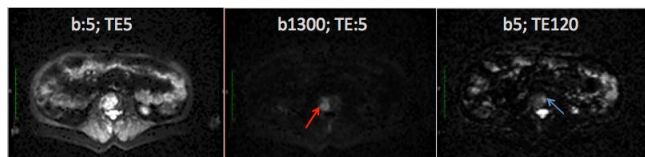

Figure 2: cDWI images of a bone metastasis patient with metastatic prostate cancer.

Prostate cancer:

In prostate cancer, using short TE (10ms) and high computed b-values (e.g. 1500 s/mm^2) can help to improve tumour delineation in the peripheral zone of the prostate gland by reducing the high T2 signal observed from the normal peripheral gland.

Discussion: In this small cohort, we were able to show that it is possible to independently vary the image contrast derived from T2 and diffusion by using computed diffusion-weighted images that take into account both ADC and the T2-relaxation time. As shown in the above examples, this provides a potentially useful clinical tool, which can be used to eliminate the effects of T2 shine through and enhance the contrast from the use of cDWI. The additional acquisition time required to acquire the data to support this technique is modest (< 2 minutes). Good image registration between the T2 and diffusion weighted is ensured by using the same EPI readout.
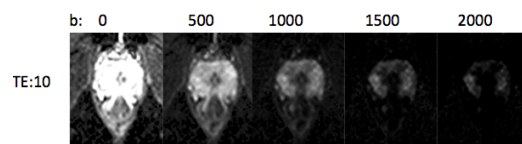

Figure 3: cDWI images of a primary prostate cancer patient.

Conclusion: The modified cDWI model which takes the T2-relxation time into account, can be used to enhance or remove T2 effects by using different echo times, which appears to be a promising tool for improving image contrast and tumour detection using body diffusion-weighted MRI.

Reference:
[1]. Koh, DM. and D.J. Collins, *Diffusion-weighted MRI in the body: applications and challenges in oncology.* American Journal of Roentgenology, 2007. **188**(6): p. 1622-1635. [2]. Blackledge, M.D., et al., *Computed diffusion-weighted MR imaging may improve tumor detection.* Radiology, 2011. **261**(2): p. 573-581.