Quantitative evaluation of diffusion weighted imaging techniques for radiotherapy of prostate cancer

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Target Audience: Radiologists, Oncologists and Physicists.

Purpose: The apparent diffusion coefficient (ADC) obtained from diffusion weighted imaging (DWI) has been shown to increase during the radiation treatment of prostate cancer[1]. However, the technique is routinely implemented using echo planar imaging (EPI) which is prone to image artefacts and geometric distortions. Recently, two new schemes have been commercially implemented to improve DWI quality; the first utilises a segmented read-out with navigator re-acquisition (RESOLVE) to reduce phase errors[2], while a second takes advantage of parallel transmission (ZoomIT) to produce shaped excitation of a reduced volume[3], thereby avoiding tissues that contribute to artefacts. If DWI is to be used to plan and monitor radiotherapy it must be shown to be robust and reliable. The purpose of this work was to evaluate three DWI techniques in terms of ADC repeatability in vitro and geometric integrity of the prostate in vivo.

Methods: All imaging was performed on a 3.0 Tesla Siemens Skyra system. A doped water phantom was imaged on a daily basis over a period of 4 weeks to assess both short (daily) and long-term (weekly) repeatability of each DWI sequence. The scanner bore and phantom temperatures were recorded throughout. ADC values were obtained and the coefficient of repeatability was used to assess both short and long-term variation (2.77 × SD). In order to quantify distortion in vivo, a total of ten normal subjects (aged between 19 and 55 years) were examined using a combined 32 channel spine coil and 18 channel body array. Imaging included the three diffusion techniques plus a standard T_2-weighted TSE acquisition which was taken as the gold standard. DWI images were fused to the T_2-w images and transferred to a treatment planning workstation (Pinnacle). The prostate gland was delineated on all slices for each sequence by an experienced Radiation Oncologist. Contours were then exported off-line for the subsequent calculation of volumes and Dice's similarity coefficients (DSC).

Results: Table 1 gives results of the phantom measurements which were all recorded within a temperature range of 0.2°C. ADC values were significantly higher with EPI compared to the other two sequences ($p < 0.001$). Both EPI and RESOLVE were significantly more repeatable short-term than ZoomIT ($p < 0.05$). Longer-term repeatability was worse but these differences were again observed although not statistically significant ($p < 0.15$). Figure 1 shows example DWI (b=50 s/mm^2) images fused to the corresponding T_2-w image. RESOLVE and ZoomIT demonstrated reduced distortion and RESOLVE produced the best match (5.5% volume difference and 0.86 DSC) with the T_2-w gold-standard.

	EPI	RESOLVE	ZoomIT
ADC (10^{-3} mm^2/s)	1.910	1.875	1.891
Short-term Repeatability†	100%	81%	386%
Long-term Repeatability†	401%	432%	765%

Table 1: ADC and repeatability measurements for each DWI sequence. †Note repeatability is normalised to the short-term EPI result.

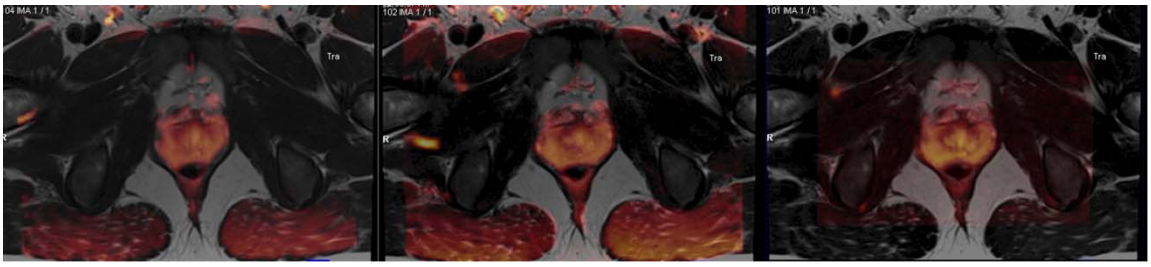

Figure 1: (left to right) b=50 s/mm^2 image fused to a T_2-w image for EPI, RESOLVE and ZoomIT with the last two showing improved registration of the prostate.

Discussion: Important differences have been shown between three DWI sequences both in terms of geometric integrity and ADC variability. RESOLVE appears to perform the best in terms of both repeatable ADC measurements and accurate anatomical contours for prostate radiotherapy.

References: [1] Park SY et al. Int J Radiation Oncol Biol Phys. 2012;83:749-755. [2] Porter DA, Heidemann RM. Magn Reson Med 2009;62:468-475. [3] Rieseberg S et al. Magn Reson Med 2002; 47:1186-1193.