Clinical Feasibility of Distortion Corrected Diffusion-Weighted (DW) Images of Human Cervix

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Target Audience: Radiologists, radiographers, physicists with interest in gynaecological MR or distortion correction methods for clinical applications of DWI

Purpose: Cervical cancer often presents at an early stage where effective cytological screening programmes exist. In young women, where fertility-sparing surgery may be possible, defining disease extent using an endovaginal receiver coil improves sensitivity and specificity of local staging [1]. Diffusion-weighted MRI recently has been employed in addition to T2-W imaging to improve the detection of cervical cancer because the apparent diffusion coefficient (ADC) of tumour is significantly lower than normal tissue [2]. However echo-planar diffusion-weighted sequences suffer from susceptibility induced and eddy-current related distortions, which are significantly worse in the presence of an endovaginal receiver coil. The purpose of this work therefore was to implement a correction for the geometric distortion present in diffusion-weighted images of the cervix acquired with an endovaginal receiver coil using Chang&Fitzpatrick's reverse gradient algorithm [3] and assess the similarity between these images before and after correction and the T2-weighted images.

Method: 41 patients were imaged on a 3.0T Philips Achieva MR system (Philips Healthcare, Best, the Netherlands) using T2-weighted (T2W) TSE images in three planes orthogonal to the cervix (field-of-view FOV=100mm, TE=80ms, TR=3400ms, fat suppression (SPIR), 2 averages, acquisition matrix 238x238, 0.42mm in-plane resolution, image matrix 288x288, 0.35mm resolution, 24 slices with 2mm slice thickness and 0.1mm separation). Two consecutive diffusion-weighted sequences were acquired in the forward and reverse gradient directions. Both were acquired coronal to the cervix using a single shot SE EPI-based sequence (FOV=100mm, TE=52ms, TR=8000ms, SPIR fat suppression, left-right phase encoding, 1 average, acquisition matrix 80x80, 1.25mm in-plane resolution, image matrix 224x224, b-values 0, 100, 300, 500 and 800smm^{-2}, 24 slices with 2mm slice thickness and 0.1mm separation). A left-right phase encoding avoided respiratory motion artefact through the cervix. The images were corrected using Chang&Fitzpatrick's reverse gradient algorithm. To demonstrate the clinical significance of the correction algorithm, two measures were considered. Firstly, the angle of the endocervical canal to the horizontal on the T2-W, forward gradient, reverse gradient and corrected b=800smm^{-2} images (which had greatest distortions) were measured by an experienced observer. Secondly, template matching utilizing normalized cross-correlation (NCC) as defined in [4] for b=0 and all b-value images was computed for the three central slices of each patient as this captured most cervix features. We chose NCC because it assumes a linear relationship between intensities and we are interested in features which maintain this relationship. This enabled evaluation of the degree of similarity using the highest correlating points calculated by template matching. Central slice was defined as the one capturing most cervix anatomy by an experienced observer. We chose image A to be either of the forward gradient, reverse gradient or the corrected diffusion image with a kernel k of size 25 x 25 pixels (8.8mm x 8.8mm) and image B to be the T2-weighted image with a search neighbourhood t of 51 x 51 pixels (18mm x18mm).

Results: Table 1 demonstrates the difference in angle measurements between T2-W and DWI, illustrated in Fig.1 for one patient. Based on the assumption that the T2-W images are ground truth, a paired *t*-test between T2W and forward gradient gave a p value of 0.007, between T2-W and reverse gradient p=0.055 and between T2-W and corrected p = 0.95. This result signifies that the angular measurements of the corrected images are highly correlated to the T2-W images and that the forward gradient images are significantly different to the T2-W images. NCC values for all patients are reported in Table 2 and NCC maps for the same patient in Fig.1 are shown in Fig.2.

Table 1	Forward	Reverse	Corrected
Difference in angle from T2W image (deg)	14.8±16.7	16.2±20.0	4.9±6.5

Table 1: Mean±SD of the difference in angle of the endocervical canal to the "horizontal" between the T2W and the a) forward gradient, b) reverse gradient c) corrected b = 800smm^{-2} images.

Table 2	Forward	Reverse	Corrected
NCC	0.68±0.15	0.69±0.15	0.68±0.15

Table 2: Mean and standard deviation of the NCC for a region-of-interest encompassing the cervix a) forward gradient, b) reverse gradient c) corrected b = 800smm^{-2} images for all patients.

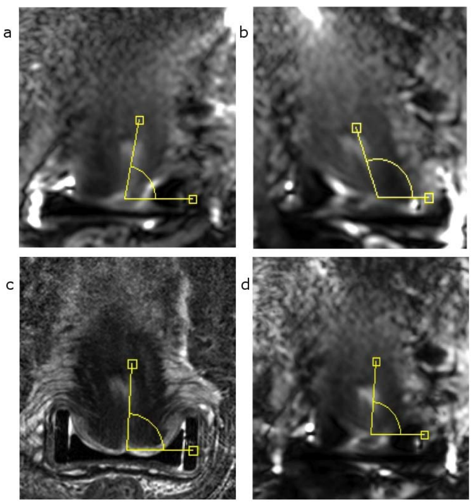

Figure 1: The angle of the endocervical canal to the "horizontal" on the coronal slice through the centre of the cervix at a field-of-view of 100mm. (a) Forward gradient b = 800smm^{-2} measures 78° (b) Reverse gradient b = 800smm^{-2} measures 109°(c) T2-W measures 86° (d) Corrected b = 800smm^{-2} measures 86°.

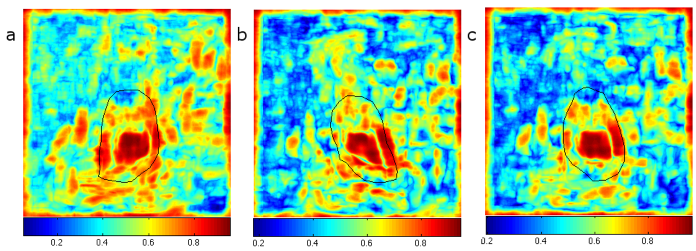

Figure 2: NCC on the coronal slice through the centre of the cervix at a field-of-view of 100mm. A region-of-interest encompassing the cervix is shown (a) Forward gradient b = 800smm^{-2} mean NCC 0.68 (b) Reverse gradient b = 800smm^{-2} mean NCC 0.71 (c) Corrected b = 800smm^{-2} NCC 0.69.

Discussion & Conclusions: Correcting distortions in diffusion-weighted images using the reverse gradient algorithm results in images, which are highly correlated to the T2-W images using the angle measurement. This is particularly useful in clinical setting where accurate localization of a tumor on a diffusion-weighted image compared with T2-W is essential. The NCC measure varied marginally between forward, reverse and corrected images. This suggests that one must investigate feature tracking techniques which are invariant to scale and orientation. We plan to develop more complex correction algorithms based on a single image acquisition, as the extra acquisition is inconvenient for the patient.

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