Repeatability of geometrically corrected DWI scans for treatment response monitoring in oesophageal cancer

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Purpose To investigate the repeatability error of geometrically corrected ADC maps, aimed at treatment response monitoring of oesophageal cancer.

Introduction Diffusion-weighted imaging (DWI) is an increasingly important tool for treatment response monitoring in cancer[1]. Response monitoring is generally based on apparent diffusion coefficient (ADC) values within the tumour volume-of-interest (VOI). For this purpose, the absolute ADC and/or changes in ADC are used. In our institute, we are currently investigating the use of DWI to predict treatment response in oesophageal cancer. Response prediction in this patient group is supposed to be crucial, as treatment response to neoadjuvant chemoradiotherapy is very diverse in this population with a ~30% chance of complete pathological response[2]. Prior to constructing a response model, we investigated the repeatability of the ADC mapping. As we observed that DWI images are geometrically distorted, we opted for retrospective correction of ADC maps prior to analysis. The retrospective correction enabled direct exchange of the tumour VOI between anatomical T_2W scans and ADC maps. Furthermore, we report the observed ADC difference during treatment.

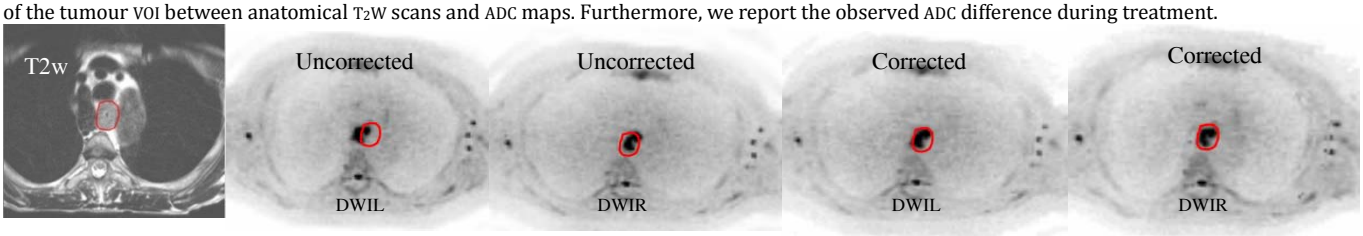

Figure 1: Original DWI scans and geometrically corrected DWI scans (both b = 800 s/mm², with phase encoding direction left of right), together with a T2w scan. Delineation was based on the T2w scan. In the original DWI scan a clear shift and deformation of the diffusion restricted area can be observed. After correction, the diffusion restricted area in DWIL and DWIR are comparable and coincide with the location of the delineation.

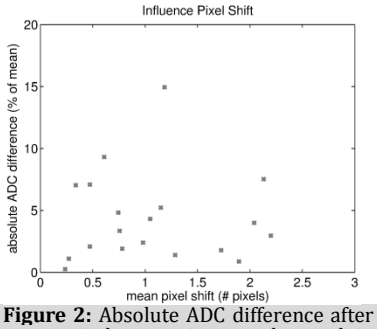

Figure 2: Absolute ADC difference after geometrical correction as observed in the tumour VOI vs. the mean pixel shift. Each data point represents one patient per scan session.

Methods Ten patients with biopsy proven oesophageal cancer were included in this IRB approved optimization study. All volunteers were asked to undergo three MRI scan sessions: before, during (week 2) and after (3.3-6 weeks) (chemo) radiotherapy (1.5T Philips Achieva, Best, the Netherlands). Due to logistical circumstances or patient's wish, two patients only underwent two scan sessions. Furthermore, an additional seven scan sessions were excluded due to receive coil malfunctioning. A total of 21 scan sessions were eligible for analysis. **MRI protocol:** Two DWI scans with opposing phase encoding directions (left or right, DWIL/DWIR) were obtained, which therefore exhibit an opposed geometrical distortion (STIR fat suppression, resolution: 3.5×3.5×4mm³, free-breathing, b = 0/200/800 s/mm², SENSE factor: 2.2, $BW_{phase,enc}$ = 29.5 Hz/voxel). Additionally, a B_0 field map was acquired with the same field-of-view as the DWI scans (spoiled-FFE, dual acquisition, TE_1/TE_2/TR = 4.6/9.2/631 ms, resolution: 4×4×4 mm³, $BW_{read\text{-}out}$ = 453 Hz/voxel). Finally, a T2W SCAN WAS obtained (MS-TSE, TE/TR = 100/1983 ms, resolution: 0.67×0.67×4 mm³, motion compensation with navigator). **Image processing:** The B_0 map was converted to a pixel shift map using $BW_{phase,enc}$. Subsequently, all DWI images (b=0, 200, and 800 s/mm²) were separately corrected for geometrical distortions[3] after unwrapping of the B_0 map (PRELUDE[4]) see example fig. 1. Finally, a mono-exponential fit was used to convert the DWI images to an ADC map. **Analysis:** The tumour was manually delineated on the pre-treatment T_2W scan by a clinician. The oesophagus was delineated over the full cranial-caudal length of the tumour (estimated on b=800 s/mm²). The tumour VOI was copied to the rigidly registered per and post treatment scans, and the axial extent of the delineated volume was adapted to compensate for tumour shrinkage. The VOI was transferred to the geometrically corrected ADC map, and the median ADC within the VOI was determined.

Results and Discussion Fig. 2 shows the absolute ADC difference as a function of the mean pixel shift. No significant correlation between the ADC difference and the mean pixel shift was observed using Spearman's rank correlation coefficient. In the Bland-Altman plot (fig. 3) a small non-significant bias of 1.1% was observed (one-sided t-test, p = 0.41). The coefficient of repeatability (CR, 1.96× standard deviation) was found to be 11.0%. The reported CR accounts for measurement noise, the effect of geometrical correction and patient motion. However, it does not take inter-observer and intra-observer variations into account, and is minimally sensitive to physiological (day-to-day) changes of the ADC as the DWI scans were recorded within a time span of 15 minutes. The median (and range) of observed differences between pre-per and pre-post ADC was 17% (8-28%) and 22% (2-41%), respectively.

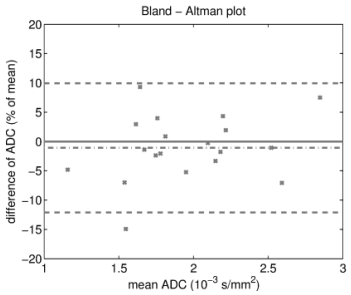

Figure 3: Bland-Altman plot of the ADC repeatability within one scan session. The dashed lines represent the 95% confidence interval, the dash-dot line is the (non-significant) bias.

Conclusion We showed that an unbiased median ADC determination of oesophageal tumours is possible after geometrical correction. The repeatability error was generally smaller than the pre-per and pre-post ADC difference (8/11 cases). Therefore, we will continue to use the proposed protocol for DWI imaging in our development of a treatment response prediction model. In the future, we will continue to include patients in order to verify the value of ADC to predict response, as the sample size lacks sufficient power. Additionally, we will analyse the inter-observer and intra-observer variability in ADC to investigate its influence on the repeatability. An advantage of the geometrically corrected DWI used in in this abstract, is that we can easily transfer the tumour VOI to other scans in the scan session.

References [1]Thoeny et al., jMRI (2010) 32:2 [2]van Hagen et al., NEJM (2012) 366:2074 [3]Jezzard et al., MRM (1995) 34:65 [4]Jenkinson et al., MRM (2003) 49:193