Repeatability of perfusion and pure diffusion parameters in a bi-exponential, multi-b diffusion imaging approach

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Introduction: Diffusion-weighted imaging (DWI) is recognized to be an important clinical tool to distinguish benign from malignant lesions or to follow treatment efficiency. In addition to classical apparent diffusion coefficients (ADC) determined with a simple fit of data obtained with 2 or 3 b values, a more complete approach involves a bi-exponential fitting of multi-b DWI datasets, leading to perfusion (low b values) and pure diffusion coefficients (high b values). It is crucial to estimate the reliability of this approach if one is to use it in a clinical setting to gain a deeper insight than the one provided by conventional ADC measurements. However, such a study has only been done on conventional ADC measurements and not data extracted from multi-b DWI datasets [1]. To investigate the reliability of such an imaging and data processing technique, the inter-observer and the inter-acquisition repeatability were studied in the case of a multi-b, bi-exponential fitting approach in patients with hepatic tumors.

Material and methods: Ten patients diagnosed with a hepatic lesion (for a total of 13 lesions) underwent two successive multi-b, free-breathing DWI acquisitions in a 1.5T Philips clinical MRI system (Philips Medical Systems, Best, The Netherlands). A spin-echo scheme with a EPI readout (TR/TE = 305/56 ms, field of view of 320 × 320 mm^2 for a 80 × 80 matrix, 3 transverse slices of 4 mm of thickness) was used to create 11 DW images (b = 0, 10, 20, 30, 40, 50, 75, 100, 150, 300 and 500 s/mm^2) for a total scan duration of 3 min 30. Average measurements of perfusion fraction (DC_{fast}), pure diffusion fraction (DC_{slow}), perfusion coefficient (ADC_{fast}), pure diffusion coefficient (ADC_{slow}) and conventional ADC were performed by 2 independent observers in each tumor, for each DWI acquisition. Differences between inter-observer and inter-acquisition measurements were evaluated by a paired Student's t-test. Intraclass correlation coefficients (ICC) as well as 95% limits of agreement expressed as percentages of mean coefficient values and extracted from Bland-Altman plots were also measured.

Results: The perfusion and pure diffusion parameters as well as the ADC measurements were similar between acquisitions (p values ranging from 0.25 to 0.73) and between observers (p values ranging from 0.29 to 0.71). Measurements reproducibility resulting of successive DWI acquisitions is high for DC_{slow} (Fig. A, 95% limits of agreement 15 – 20 %), ADC_{slow} (ICC = 0.831 and 95% limits of 24 – 32 %) and conventional ADC (ICC = 0.8502 and 95% limits of 29 – 32 %). Inter-observer repeatability of DWI data processing is very high for any considered parameter (ICC ranging from 0.844 to 0.924 and 95% limits of agreement ranging from 5 % to 25 %) except ADC_{fast}. The perfusion coefficient calculated in the low b values appeared to be highly unreliable, with an intra-acquisition ICC of 0.621 and 95% limits of agreement of 87 – 98 % (Fig. B).

Conclusion: A maximal overall variation in DWI measurement of 32% was observed for the most reliable and repeatable parameters (DC_{fast}, DC_{slow}, ADC_{slow} and conventional ADC), whereas ADC_{fast} appeared to be unreliable. A multi-b, bi-exponential approach necessitates the determination of 4 parameters instead of 2 in a conventional mono-exponential approach, which diminishes the level of repeatability of the technique. One could suggest that improved DWI acquisitions limiting respiratory motion artefacts could lead to more reliable measurements. The technique is however reliable enough to offer some insight on hepatic tumors, at the condition that the observed perfusion and pure diffusion changes are above 32%.

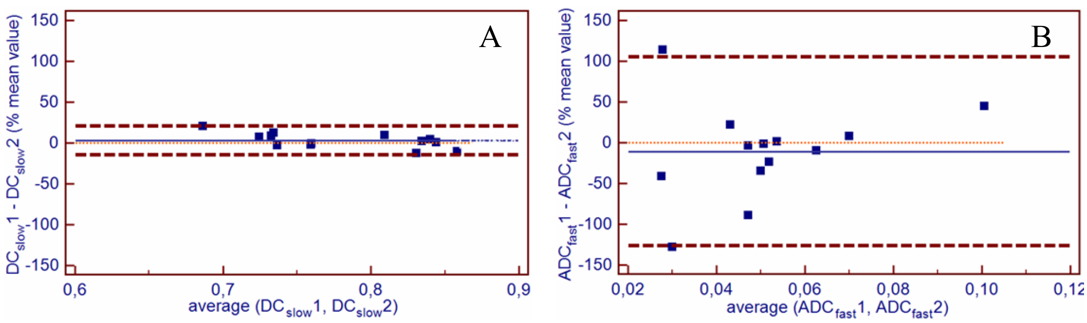

Fig. A : Bland-Altman plot of inter-acquisition DC_{slow} measurements (represented as % mean value); Fig. B: Bland-Altman plot of inter-acquisition ADC_{fast} measurements (represented as % mean value).

1. S.Y. Kim et al., Radiology 255 : 815 (2010)