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MR neurography of the median nerve at 3.0 T: Optimization of diffusion tensor imaging and fiber tractography

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ABSTRACT

Objectives: The purpose of this study was to systematically assess the optimal *b*-value and reconstruction parameters for DTI and fiber tractography of the median nerve at 3.0 T.
Methods: Local ethical board approved study with 45 healthy volunteers (15 men, 30 women; mean age, 41 ± 3.4 years) who underwent DTI of the right wrist at 3.0 T. A single-shot echo-planar-imaging sequence (TR/TE 10123/40 ms) was acquired at four different *b*-values (800, 1000, 1200, and 1400 s/mm^2). Two independent readers performed post processing and fiber-tractography. Fractional anisotropy (FA) maps were calculated. Fiber tracts of the median nerve were generated using four different algorithms containing different FA thresholds and different angulation tolerances. Data were evaluated quantitatively and qualitatively.
Results: Tracking algorithms using a minimum FA threshold of 0.2 and a maximum angulation of 10° were significantly better than other algorithms. Fiber tractography generated significantly longer fibers in DTI acquisitions with higher *b*-values (1200 and 1400 s/mm^2 versus 800 s/mm^2; $p < 0.001$). The overall quality of fiber tractography was best at a *b*-value of 1200 s/mm^2 ($p < 0.001$).
Conclusions: In conclusion, our results indicate use of *b*-values between 1000 and 1400 s/mm^2 for DTI of the median nerve at 3.0 T. Optimal reconstruction parameters for fiber tractography should encompass a minimum FA threshold of 0.2 and a maximum angulation tolerance of 10.

1. Introduction

Recently, several pilot studies describing the application of diffusion tensor imaging (DTI) and fiber tractography to peripheral nerves have been published [1–9]. They reflect the increasing interest in the assessment of functional integrity of the peripheral nervous system by means of magnetic resonance imaging (MRI).

DTI is a MRI technique that reveals micro structural characteristics of biological tissues containing highly organized microstructures (e.g. myelin sheath or axon cylinders), given that in these tissues water cannot freely diffuse in all directions. This directional inhomogeneity of diffusion is called anisotropy. Diffusion can be quantified using metrics such as the apparent diffusion coefficient (ADC) and fractional anisotropy (FA) [10]. Fiber tractography is used to visualize DTI data and to facilitate FA and ADC measurements along a certain distance of the nerve's course rather than at focal locations. The most common method is to propagate a line from a seed point by following the local main diffusion orientation. Voxels with similar diffusion tensor characteristics can thus be connected and visually displayed on color-coded three-dimensional images, as has been demonstrated also in peripheral nerves [1,10].

While DTI is a well-established technique in the central nervous system, an application to the peripheral nervous system is however challenging due to its lower water proton density, the smaller nerve size and image distortion artifacts [11]. In addition, many basic methodological questions remain unclear how peripheral nerves should be imaged. Basic work regarding the optimal imaging parameters was performed by Andreisek et al., who systematically evaluated the optimal *b*-value for imaging at 1.5 T [1]. A *b*-value of 1025 s/mm^2 was identified as optimal for DTI and fiber tractography at 1.5 T. The *b*-value is the primary (user-defined) parameter determining the sensitivity in a diffusion-weighted sequence. Increasing *b*-values cause increased diffusion weighting of a DTI acquisition but at an expense of a lower

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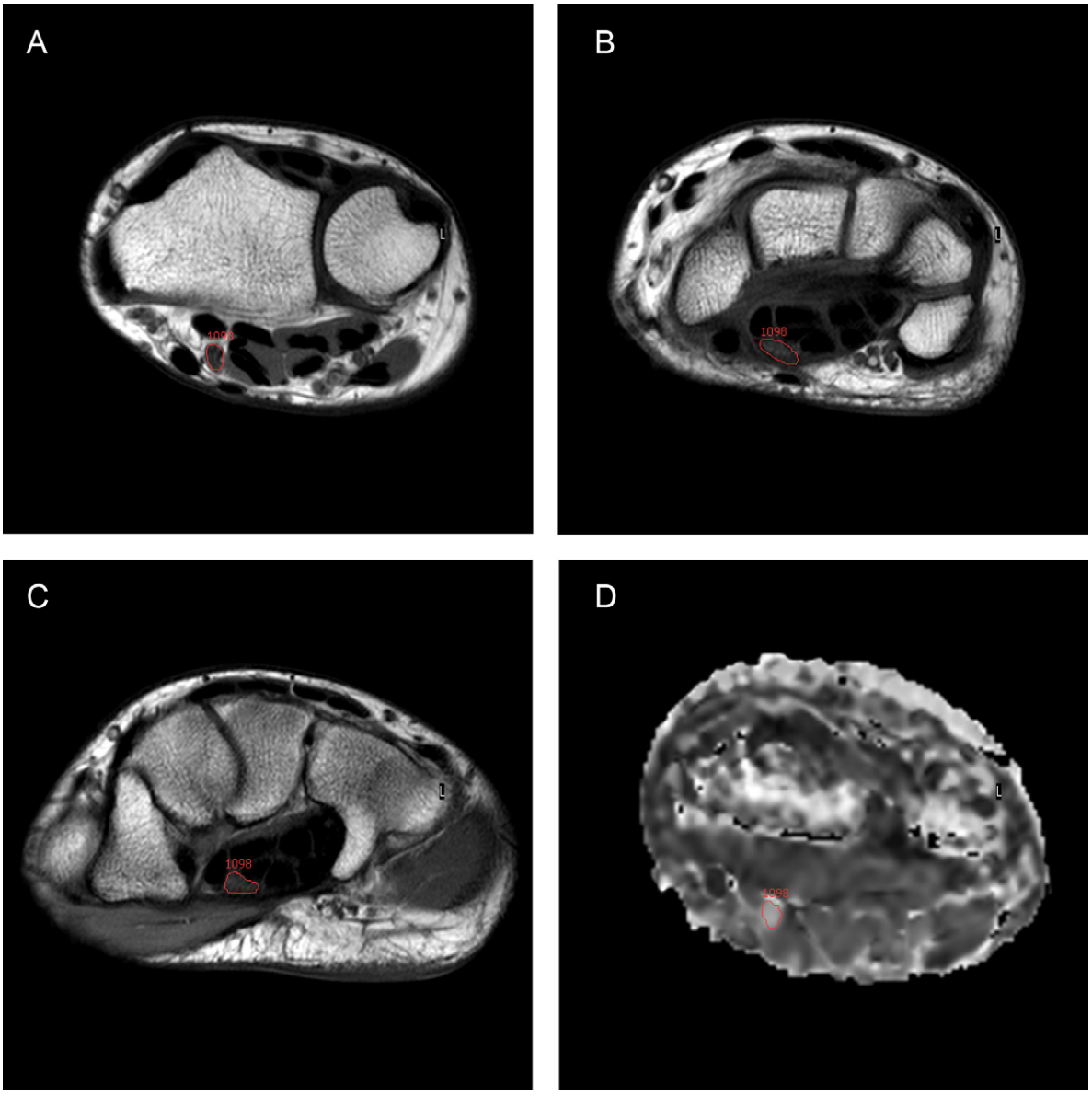

Fig. 1. (a–d) Transaxial T1-weighted TSE MR images of a healthy volunteer at the level of the distal radioulnar joint (a), pisiform bone (b) and hamate bone (c) illustrate placement of seed regions of interest (ROIs) with each ROI encompassing the median nerve. (d) Corresponding FA map at the level of the distal radioulnar joint (section location identical to Fig. 1A) shows increased grayscale values representing higher FA values at the anatomic location of the median nerve and lower grayscale values representing lower FA values within the surrounding tissues.

signal-to-noise ratio (SNR) [1,3–5,12–14]. At present, the optimal *b*-value for tractography at higher field strengths (i.e. 3.0 T) is still unknown, although it is expected to be higher than at 1.5 T since 3.0 T MR systems offer a theoretical almost twofold increase in SNR compared to 1.5 T MR systems. Thus, the first purpose of this study was to systematically assess the optimal *b*-value for DTI and fiber tractography of the median nerve at 3.0 T using a dedicated multi (8)-channel surface array wrist coil.

Another important methodological question is related to the optimal post processing. In previous literature, a variety of reconstruction parameters has been used [1,2,4,9,10] for different software and at present, no accepted standard exists for post processing. The few reports available are from studies in the central nervous system but not from peripheral nerves [15]. However, regardless of which software is used, most require the input of FA threshold values and angulation tolerances, which both determine the limits of automatic fiber tracking of fibers through user defined seed regions of interest (ROIs). Thus, the second purpose of this study was to assess the best reconstruction parameters for fiber tractography of the median nerve at 3.0 T.

2. Materials and methods

2.1. Study subjects

This prospective cross-sectional study was approved by the institutional review board (IRB approval number (KEK-ZH-Nr.), 2009-0133/5). Written informed consent was obtained from all study subjects.

Between April and June 2010, 45 healthy volunteers were included in this study (15 men, 30 women; median age, 39 years; mean age, 41 ± 3.4 years; age range, 22–66 years). Inclusion criterion was age >18. Exclusion criteria were general contraindications for MRI, pregnancy, history of prior hand or wrist surgery and cardiovascular, pulmonary, endocrine, metabolic, neurological, neuromuscular, or wrist-related musculoskeletal disorders. All 45