

Diffusion-weighted MRI of musculoskeletal soft-tissue tumors using a RARE-based single-shot pulse sequence

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Introduction

Whereas diffusion-sensitized single-shot EPI sequences are now regarded as the standard approach for diffusion-weighted imaging (DWI) and diffusion tensor imaging of the brain, no such agreement exists with respect to DWI outside the brain. Several alternative techniques for DWI of musculoskeletal structures have been applied, including spin echo (SE) or stimulated echo sequences, line scan imaging techniques, MR sequences with radial k-space acquisition, steady-state free precession sequences, segmented EPI sequences, and single-shot sequences based on the acquisition of a series of spin echoes (fast/turbo spin echo methods). This last group appears especially promising for robust DWI in clinical routine because these sequences are less motion-sensitive due to the single-shot approach and the acquisition of multiple spin echoes is less sensitive to susceptibility artifacts than the EPI readout. The purpose of this study was to evaluate the feasibility of a single-shot multi spin echo sequence for DWI of soft-tissue tumors in the musculoskeletal system.

Materials & Methods

The sequence evaluated in this study is a centric-reordered RARE (rapid acquisition with relaxation enhancement) version of the diffusion-weighting “displaced U-FLARE” sequence suggested by Norris et al. in 1992 [1]. In evaluation of this sequence, DWI was performed in a liquid phantom (consisting of 4 cylinders filled with acetone, water, polyethylene glycol (PEG), and dimethyl sulfoxide (DMSO)), in excised human tumor samples embedded in bovine muscle, and in 9 patients suffering from different types of soft-tissue tumors. We compared the sequence with a diffusion-weighting SE sequence (only in the phantom and tumor samples) and with an EPI diffusion sequence. All measurements were performed on 1.5 T whole-body MR systems (Magnetom Sonata and Magnetom Symphony, Siemens, Erlangen, Germany). We applied diffusion weightings (b-values) of 50, 250, 500, and 750 s/mm².

Results

The phantom measurements in water and DMSO showed a difference of less than 5 % comparing the apparent diffusion coefficients (ADCs) determined by the mRARE sequence and the two other techniques. The reproducibility varied between 92.6 % and 99.6 % for the ADC measurements in water, PEG, and DMSO, and between 44.2 % and 98.2 % in acetone. Comparing mRARE and EPI, the differences in the ADC were about 10 % in the excised tumor tissue and typically about 15 % in vivo. Absolute ADC values between 0.8 and 1.4×10⁻³ mm²/s were found in solid tumor tissue, agreeing well with those of other publications [2, 3]; in cystic tumor areas, ADCs greater than 2.0×10⁻³ mm²/s were determined with the mRARE and the EPI sequence. As shown in Fig. 1, diffusion-weighted images of the mRARE sequence were less distorted than those acquired with the single-shot EPI sequence and provided more anatomic information since muscle and fat signals were considerably higher.

Conclusions

We have demonstrated that the described mRARE sequence is feasible for the acquisition of diffusion-weighted images of musculoskeletal soft-tissue tumors and for the quantification of the ADC in tumors. Reduced geometric distortions and better anatomic information recommend the mRARE diffusion sequence for further studies in larger patient groups with musculoskeletal tumors aimed e.g. on differentiation of benign and malignant lesions or of tumor recurrences and post-therapeutic soft-tissue changes [4].

References

[1] Norris DG, Bornert P, Reese T, Leibfritz D [1992] Magn. Reson. Med. 27:142–164. [2] van Rijswijk CS, Kunz P, Hogendoorn PC, Taminiau AH, Doornbos J, Bloem JL [2002] J. Magn. Reson. Imaging 15:302–307. [3] Einarsson H, Karlsson M, Wejde J, Bauer HC [2004] Eur. Radiol. 14:959–963. [4] Baur A, Huber A, Arbogast S, Durr HR, Zysk S, Wendtner C, Deimling M, Reiser M [2001] Eur. Radiol. 11:828–833

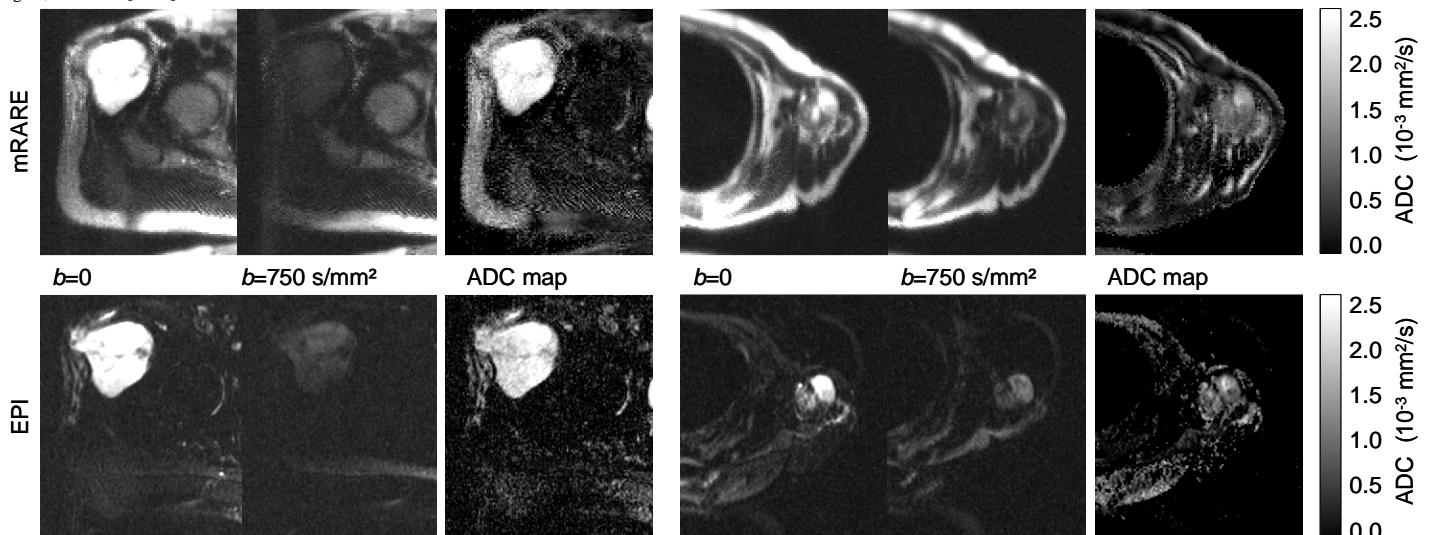


Figure 1: Diffusion-weighted images ($b=0$ and 750 s/mm^2) and ADC maps of two patients suffering from a myxoid liposarcoma at the lateral side of the proximal femur (images on the left hand side) and from an osteosarcoma in the left humerus (images on the right hand side) acquired with the mRARE sequence (top row) and EPI sequence (bottom row).