Dynamic Contrast Enhanced MRI of the Brain at 7 T

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Introduction

In dynamic contrast enhanced (DCE-) MRI, parameter maps are calculated from the time course of contrast enhancement. The maps are used to characterize brain lesions according to their perfusion properties and contrast leakage, which can be especially useful in highly vascularized tumors like glioblastoma multiforme (GBM) [1,2]. These parameters can be used for therapy planning and monitoring, and to identify tumor recurrence. Like in most functional imaging methods, the spatial resolution is often sacrificed for a high temporal resolution. To show the feasibility of DCE-MRI at 7 T and to improve the spatial resolution, we adapted DCE imaging to ultra high field MRI at 7 T.

Methods

To monitor the time course of contrast enhancement and to derive quantitative parameters like the transfer constant k_{trans}, a bolus of contrast medium has to be tracked with a sufficient temporal resolution. For this purpose, we used a T1-weighted angiographic MRI sequence (TWIST) on a B_0 = 7 T whole body system (Magnetom 7 T, Siemens, Erlangen, Germany), using a 24-channel Tx/Rx head coil (Nova Medical, Wilmington, VA).

To optimize the SNR and CNR, we performed single-slice measurements with flip angles of 9°, 7°, 6°, and 5°. SNR and CNR were calculated by dividing the signal in the tumor by the noise signal outside of the brain for SNR and by the signal in normal brain for CNR.

To achieve an adequate temporal resolution of about 3 s for the calculation of an arterial input function (AIF), the TWIST sequence parameters were set to a temporal resolution of 2.6 s, resulting in a TR of 2.8 and a TE of 1.23 ms. To increase the acquisition matrix from 128×96 voxels at 3 T to 256×173 voxels at 7 T, parallel acquisition was increased from factor 2 at 3 T to factor 4 at 7 T. This was possible because the signal loss from parallel acquisition was partially offset by the increased signal strength at 7 T. Thus, an in plane resolution of 1.0x0.9 mm^2 at a slice thickness of 1.2 mm could be achieved.

During DCE-MRI, a normal dose of 0.1 mmol Gd/kg body weight was injected at a rate of 3 ml/s. Over the duration of 6 min, 140 dynamic 3D TWIST data sets were acquired with coverage of 32 slices with 1.2 mm each. We examined two patients, one with a high-grade astrocytoma and another with a multiple myeloma.

The dynamic data was transferred to an external workstation and evaluated according to the Tofts model using the software package DynaLab 3.2 (Fraunhofer MEVIS, Germany) [4]. In particular, k_{trans} maps were calculated, and the values in the lesions were compared to the healthy contralateral side.

Results

The best SNR of 24.1 and CNR of 2.36 were achieved at a flip angle of 9°. In both clinical cases, the k_{trans} maps (Fig. 1) show well-delineated lesions.

Compared to dynamic susceptibility contrast (DSC-) MRI, the increased signal is limited to the lesions and there is no disturbingly high signal in vessels, which could be mistaken for tumor tissue. The inhomogeneous distribution of permeability can be demonstrated in both tumors (Fig. 2).

Conclusions

The T1-weighted angiographic TWIST sequence could be successfully used at a field strength of 7 T. Applying this technique to brain tumors, we could show an excellent delineation of the lesion on the permeability maps (k_{trans}). The increase in resolution can be used for a better characterization of tumor heterogeneity, which can be useful in the targeted biopsy of such lesions, as well as to quantify the heterogeneity of the contrast enhancement [5].

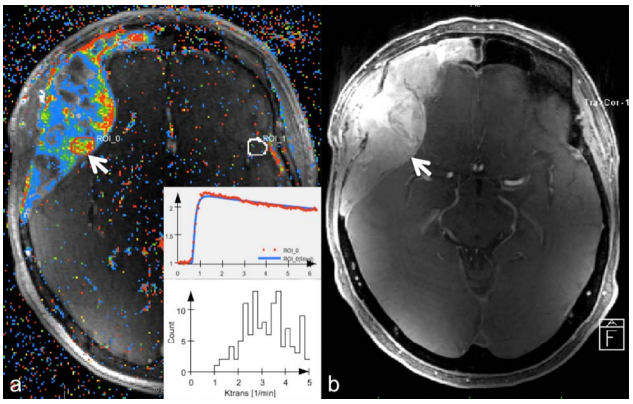

Fig. 2: k_{trans} map (a) in a patient with multiple myeloma. The circled region (arrow) represents an area of increased permeability (k_{trans}), which cannot be differentiated in T1-weighted imaging (b). The upper curve shows the time course of contrast enhancement, below is the distribution of k_{trans} in the region of interest (ROI).

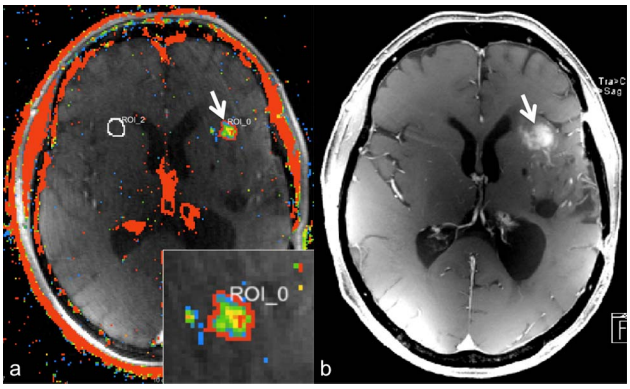

Fig. 1: k_{trans} map (a) in a patient with high-grade astrocytoma (arrow). Due to the high resolution of approximately 1 mm in plane, heterogeneous areas of permeability can seen inside the tumor, which cannot be differentiated in conventional T1w imaging (b).

References

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