7-Tesla Time-Resolved Contrast-Enhanced 3D MRA (TWIST) of the Intracranial Vessels

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Introduction:

Contrast-enhanced (CE) three-dimensional (3D) magnetic resonance angiography (MRA) of the intracranial vessels has become well established as a safe, reliable, and accurate technique for the evaluation of vascular pathologies at 1.5T [1] and has shown promising results for 3T MRA [2]. When pushing the limits towards time-resolved 3D CE-MRA of the intracranial vessels, the signal-to-noise ratio (SNR) achievable at 1.5T can be a limiting factor in simultaneously supporting the desired high spatial and temporal resolution. Ideally, the tortuous small caliber intracranial vessels are to be depicted in all three dimensions with isotropic high spatial resolution. Additionally, dynamic information of the blood flow kinetics is a critical parameter in the evaluation of vascular pathologies such as arterio-venous malformations (AVM). In this study we performed time-resolved high-field 3D CE-MRA of the intracranial vessels on a 7T whole-body MR scanner using the TWIST (Time-resolved angiography WIth Stochastic Trajectories) technique with the intent to push the limits of high spatial and high temporal resolution.

Methods and Materials:

All examinations were performed on a 7-Tesla whole-body MRI system (Magnetom 7T, Siemens Medical Solutions, Erlangen, Germany) equipped with a gradient system capable of 45 mT/m maximum amplitude and a slew rate of 220 mT/m/ms. An 8-channel transmit/receive head coil (Rapid Biomedical, Würzburg, Germany) was used for signal transmission and reception. Intracranial MRA was performed on a healthy volunteer and on five patients with known vascular pathologies. Written consent was obtained from all subjects prior to the examination. The high-field TWIST imaging parameters were optimized towards providing high spatial and temporal resolution with good image quality while providing sufficient volume coverage to cover the intracranial vessels. Imaging parameters were: TR/TE = 4.84/1.65 ms , FOV 247 x 224 mm^2, flip 11°, BW 570 Hz/pixel, 88 slices, matrix 512 x 512 interpolated to 1024 x 1024, slice thickness 2 mm, in-plane resolution 0.5 x 0.5 mm^2; temporal resolution per 3D data set 4s interpolated to 2s, 7 measurements interpolated to 12 phases. A 5 ml volume of contrast agent (Dotarem, Guerbet, Roissy Cedex, France) was manually administered with a flow rate of 2-3 ml/sec and flushed with 20 ml of saline at the same flow rate. TWIST data acquisition was initialized before contrast injection to result in a full data set without enhancement. Contrast-timing was then synchronized such that TWIST data acquisition was performed during first-pass arterial enhancement of the intracranial vessels.

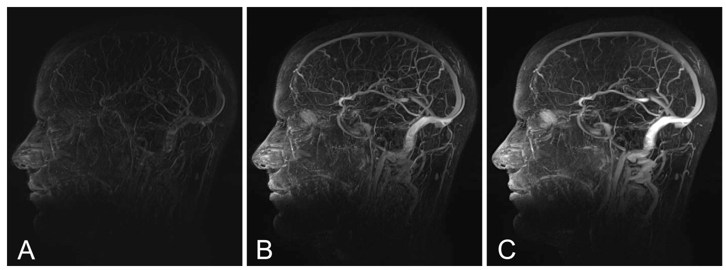

Fig. 1: 7T high-resolution, time-resolved 3D CE-MRA of the intracranial vessels of a healthy volunteer. Three out of seven acquired contrast phases are shown as sagittal maximum-intensity-projections (MIPs).

Results:

All examinations were successful and all 6 subjects tolerated positioning inside the 7-Tesla MR system, the examination time, and the administration of contrast agent well. The 8-channel transmit/receive head coil provided sufficient volume coverage to cover the intracranial vessels of interest with high and homogeneous signal. The TWIST sequence provided dynamic 3D CE-MRA of the intracranial vessels with excellent spatial detail. The temporal resolution was sufficient to resolve the first-pass of the contrast agent into several dynamic phases. The 3D dynamic MRA data is automatically reconstructed in the form of source images as well subtracted maximum-intensity-projections (MIP), each showing a different contrast phase (Fig. 1 and Fig. 2). The number of non-interpolated data sets to be acquired is currently limited by the system hardware to 7.

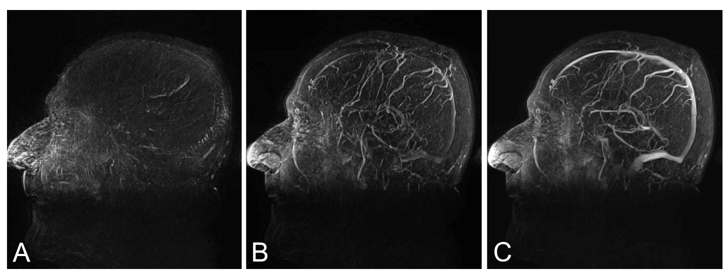

Fig. 2: TWIST 3D CE-MRA of the intracranial vessels of a patient with known right hemispherical frontoparietal hemorrhage and perifocal edema and suspicion of an associated vessel malformation. Note: The suspected vessel malformation could not be confirmed by the dynamic 3D CE-MRA.

Discussion:

High-field dynamic 3D CE-MRA of the intracranial vessels has been achieved through the use of the TWIST technique on a 7T MR system. This approach provided morphologic as well as functional MR angiographic information of the intracranial vessels with high spatial and temporal resolution while using only small amounts of contrast agent (5 ml). While the 7T field strength provides the SNR necessary to simultaneously support high spatial and temporal resolution, the enormous amount of acquired data per unit time clearly is a limiting factor. Due to hardware constraints, the reconstruction computer in the current setup limits the number of acquired data sets to 7. This limits the overall time window for data acquisition and might not be sufficient to cover the full first-pass dynamics of the contrast agent. Owing to the high field strength and the associated SAR limitations, the flip angle had to be reduced from 25° to 11°, which potentially results in suboptimal vessel-to-background contrast. Future work will focus on eliminating these limitations. Furthermore, it will be the focus of further examinations to weigh spatial and temporal resolution to tailor the high-field TWIST MRA imaging protocol to the individual vascular pathology under investigation.

References:

1. Lubicz B, et al., J Neuroradiol. 2007 34:190-7.
2. Villablanca JP, et al., Invest Radiol. 2006 41:799-805.