Targeted HASTE (TASTE) Real-Time Imaging with Automated Device Tracking for MR-Guided Needle Interventions

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Introduction

MR-guided percutaneous needle interventions are difficult to perform in closed-bore high field MR scanners, since access to the patient is extremely limited and needle artifacts are highly dependent on the choice of imaging pulse sequence and phase encoding direction. In general, pulse sequences utilising spin-echoes are favorable for imaging of the needle artifact, however, image acquisition times can be prohibitive. Single shot spin echo techniques such as RARE or HASTE reduce the total imaging time at the expense of blurring artifacts in phase encoding direction. In this work a HASTE pulse sequence for device tracking was developed, which offers automated slice positioning and real-time imaging. To reduce blurring and image acquisition time, only a small strip centred at the pathway of the needle is imaged (targeted HASTE, TASTE). The pulse sequence used a magnetisation restore pulse to improve SNR and introduce additional T2-contrast. TASTE imaging experiments were performed with a robotic assistance system [1,2]. The head of the system was equipped with tracking rf coils [3] for automated localisation [4,5] and a puncture experiment was performed in a phantom under real-time TASTE guidance.

Materials and Methods

The robotic assistance system InnoMotion (InnoMedic, Herxheim, Germany) is a fully MR-compatible pneumatically driven robotic arm for percutaneous interventions in closed-bore whole-body scanners. The system was used in a 1.5T MR scanner (Siemens Magnetom Symphony, Erlangen, Germany) with 8 independent receiver channels. For localisation the head of the robotic arm was equipped with 3 small solenoid coils (6 turns, ∅ = 5mm). The coils were embedded in PMMA spheres filled with a Gd-DTPA solution (T1 ≈ 50 ms). Each coil was connected to a separate receiver channel via an adjustable impedance matching circuitry. To avoid rf heating from induced voltages rf-chokes were incorporated between pre-amplifier and tracking coil.

The TASTE sequence sampled 4 Hadamard-encoded [4] projection data sets [5] ($t_{acq} \approx 25$ ms) before image acquisition to localise the tracking coils. Position information of the 3 tracking coils was used to adjust the slice orientation in real-time. In the subsequent HASTE imaging section, the imaging volume was restricted to a small strip parallel to the needle axis using orthogonal slice orientations for 90° rf excitation and 180° refocusing (LoLo [6], Inner Volume Imaging [7]). At the end of the TASTE echo train a 90° flip back pulse (DEFT [8,9,10]) could be used to store remaining transverse magnetisation for the next image acquisition.

Prior to the intervention the penetration point was defined graphically on previously acquired high-resolution planning images. A commercial low-artifact titanium coaxial puncture needle (Daum, Schwerin, Germany, insertion length 100 mm, ∅ 20 G) was then moved automatically to the penetration point at the surface of a gelatin phantom. While the needle was manually advanced into the target (kiwi), real-time TASTE images were displayed to the interventionalist on an in-room monitor.

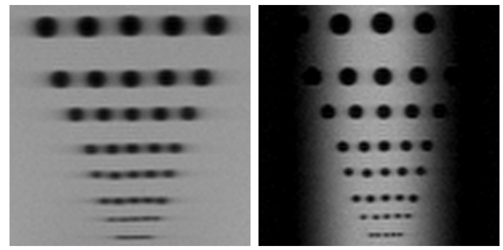

Fig. 1: *Resolution phantom imaged with a HASTE sequence (left) with full FOV and TR / TE = 1460 ms / 85 ms and a TASTE sequence (right) with 34% FOV reduction resulting in TR / TE = 560 ms / 85 ms.*

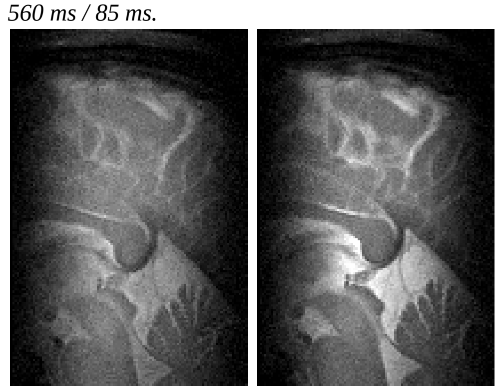

Fig. 2: *Sagittal TASTE image of the brain without (left) and with (right) DEFT pulse (TR / TE = 2000 ms / 105 ms, matrix = 256 x 104, resolution = 0.98 x 0.98 x 5 mm^3, 2 averages, BW = 100 Hz / pixel).*

Results and Discussion

Compared to conventional HASTE MRI, the TASTE sequence significantly reduced both blurring and image acquisition times (Fig. 1). The DEFT pulse improved SNR for tissues with high T1/T2 ratios such as CSF (Fig. 2). The robot-assisted puncture of the phantom could be performed with automated slice positioning at an image frame rate of 1.25 Hz (Fig. 3). The images yielded good contrast between needle and tissue and needle artifacts were significantly reduced over gradient echo sequences. With the TASTE sequence the operator could concentrate on the intervention without having to adjust imaging parameters, which might help to simplify MR-guided needle interventions.

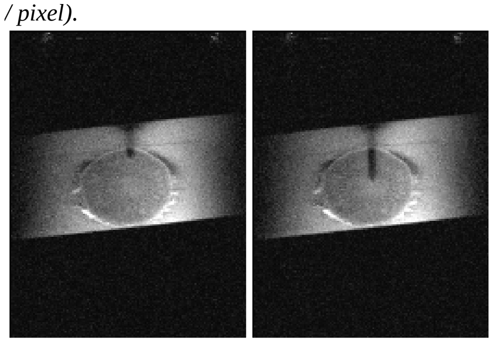

Fig. 3: *Two real-time TASTE images acquired during needle insertion (TR / TE = 800ms / 47ms, matrix = 128 x 64, resolution = 0.78 x 0.78 x 5mm^3). The needle position was always centred in the images by the automatic slice positioning.*

References

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