Local-Look HASTE MRI with Interactive Slice Positioning for an Active Needle System

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Introduction

In interventional MRI small rf coils are used to localise [1] and track [2,3] medical devices. In this work a prototype needle holder [4] with three micro-coils for localisation is used in combination with a dedicated user interface [5] for interactive scan plane orientation. The aim was to implement a Local-Look HASTE pulse sequence [6] to image the needle pathway at a highly reduced phase field-of-view without backfolding and with minimised susceptibility artefacts.

Materials and Methods

Needle Holder with Micro Coils

A prototype Plexiglas needle holder was constructed (Fig. 1b) and equipped with three small solenoid coils (6 turns, ∅ = 5mm) for localisation. The coils were embedded in spheres (Fig. 1a) filled with a GdDTPA solution (T1 ≈ 50 ms). Each coil was connected to a separate receiver channel via an adjustable tune/match circuitry. To avoid rf heating from induced voltages an rf-choke was incorporated between pre-amplifier and coil. A commercial low-artefact titanium coaxial puncture needle (Daum, Schwerin, Germany, insertion length 100 mm, ∅ 16G) was attached to the holder.

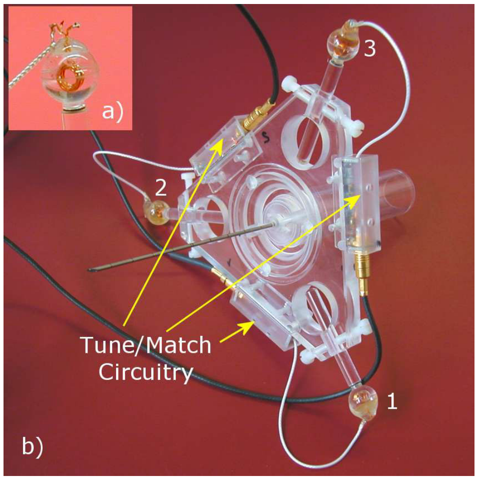

Fig.1: Prototype active needle holder with 3 micro coils for localisation.

Pulse Sequences and User Interface

Fast imaging sequences (FLASH, trueFISP, HASTE) were modified and implemented on a clinical 1.5 T whole body scanner (Siemens Magnetom Symphony, Erlangen, Germany) with eight independent receiver channels. To localise the micro coils, four Hadamard-encoded projection data sets [2,3] were acquired (t_{acq} ≈ 25ms) between two consecutive images [3,7] and the position information of the three marker coils was used to adjust the slice orientation in real time. Two different slice orientation modes could be selected: In the *in-plane mode* the slice was oriented parallel to the needle axis, whereas in the *orthogonal mode* the slice orientation was set perpendicular to the needle. Additionally, slice offset and in-plane rotation could be modified. Switching between the different modes was possible at runtime through a custom-made user interface [5]. To monitor the advancement of the needle with both minor imaging artefacts and frame rates of more than 1 Hz, a local-look HASTE sequence was implemented [6]. The local-look technique allows to restrict the imaging volume to a small strip parallel to the needle axis using orthogonal slices for 90° spin excitation and 180° refocusing (Fig. 2a). The following imaging parameters were used for LoLo-HASTE imaging: TR = 500 ms, TE = 35 ms, FOV = 75x300 mm^2, matrix = 34x256, slice thickness = 6 mm, bandwidth = 500 Hz/pixel. For LoLo-HASTE MRI an oil-filled target (vitamin pill, ∅ 9 mm) was inserted into a grape fruit and the needle was advanced to the target under MR-guidance (Fig. 2b).

Results and Discussion

The advancement of the puncture needle into a phantom could be observed with 2 fps in the LoLo-HASTE images after prior orientation with the realtime interface. Needle artefacts were highly reduced compared to prior gradient echo images. Due to the small number of phase encoding steps (34), which result in a shorter HASTE echo trains, image blurring in phase encoding direction is significantly reduced, while at the same time the total rf energy deposition during imaging remains below currently accepted SAR levels. For multiple repetitions of the LoLo-HASTE sequence a T1-contrast is established, which is also a current limitation of the technique in tissues with long T1 values. However, longer effective echo times can be used with no penalty in imaging speed through echo reordering, so that in combination with a final magnetisation restoration rf pulse (DEFT, [8]) also a T2-contrast can be established at comparable imaging speed.

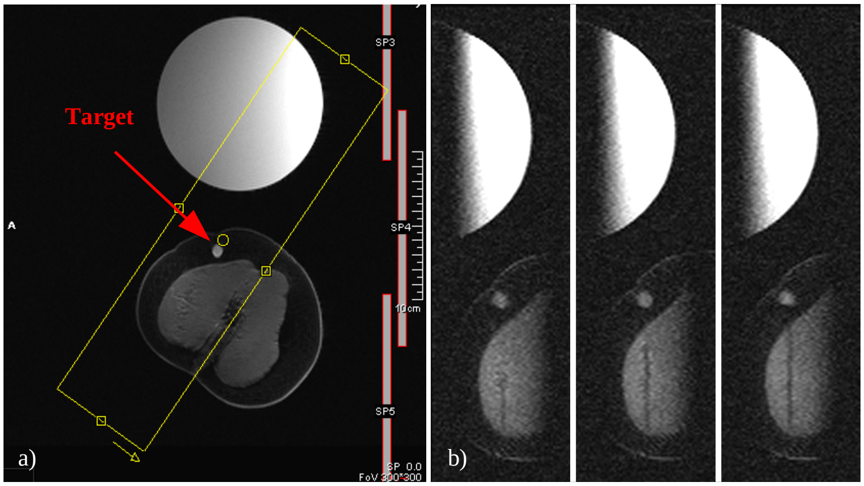

Fig. 2: (a) Orientation of the LoLo-HASTE imaging strip (yellow box) in the grape fruit. (b) Advancement of the needle to the target under continuous LoLo-HASTE imaging.

References

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