Real-time Peripheral Magnetic Resonance Angiography: An Interactive Single-Station/Single-Injection Method

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Introduction

A large anatomic coverage is required in the diagnosis of peripheral vascular disease. In continuously moving-table peripheral contrast-enhanced MR angiography (CE-MRA), a large field-of-view (LFOV) image is built up from hybrid (x, k_y, k_z)-space data as a smaller local FOV_x is translated along the patient in the x-direction.[1,2] To achieve optimal image quality, the translation of the table and the data acquisition need to be synchronized with the arterial passage of the contrast agent.[3] Recently, a 3D LFOV imaging technique was proposed to allow one to follow the passage of the contrast material in conjunction with fast reconstruction of the hybrid-space data.[2] Undersampled phase-encoding acquisition strategies necessary because of the restricted acquisition time in contrast imaging, were proposed[4] and implementation challenges were addressed.[5] In this work, we present the experimental evaluation of this technique for angiography in the lower extremities. For proof of concept, the technique was tested on a vascular phantom. The results show the feasibility of interactively following the contrast down the legs in real-time to produce a comprehensive 3D image of the entire peripheral arterial tree with a single bolus injection.

Methods

A 3D fast spoiled gradient-recalled echo pulse sequence was modified to work in real-time mode with undersampled phase-encoding acquisition patterns.[4] Custom-designed software reads the MR data directly from scanner memory, fills the hybrid-space and reconstructs the images continuously. The patient table position is determined and integrated with the sampled readout echoes at every TR for accurate filling of hybrid-space.[5] Overlapped acquired data was produced due to the potentially stochastic acquisition patterns and arbitrary table motion, and were averaged to minimize gradient geometric distortion. A large vascular phantom was built and scanned on a 3 T MR scanner (Signa; GE Medical Systems, Waukesha, WI) using a body coil. The phantom was built of plastic tubes of various diameters filled with water pumped at average of 1.2 L min^{-1}. A floating table was moved manually according to the visualized contrast flow. Typical scanning parameters were: undersampled elliptic-centric TRICKS acquisition[6] of 12% to 15% hybrid-space coverage, TR/TE 5.0 ms /1.1 ms, FOV 40 cm × 40 cm, acquisition matrix 160-256 × 128-256 × 16-32, slice thickness of 2 mm, LFOV matrix 768 × 128-256 × 16-32, scan time of 60 s to 90 s. Real-time projection images (from the 3D acquisition) were provided to the operator at about 10 frames per second. Data acquisition was performed during automatic injection of 20 mL MR contrast (Magnevist; Berlex, Berlin, Germany) at 1-2 mL s^{-1}.

Results

The contrast material was successfully tracked in real-time during the data acquisition. Figs. 1a-c illustrate three snapshots of the real-time FOV_x-sized image at 5 s, 20 s and 70 s after the injection of the contrast material. Fig. 1d is the table motion profile during the acquisition. Fig. 1e shows the large, continuous, contrast-enhanced projection image of the phantom. The tubes are visualized with minimal artifact. Note that the non-uniform velocity and the reverse motion of the table at 32 s (circled in Fig. 1d) did not affect the image quality. No difference was seen when applying phase twisting along each readout data for subpixel registration required in constant table motion methods.[1]

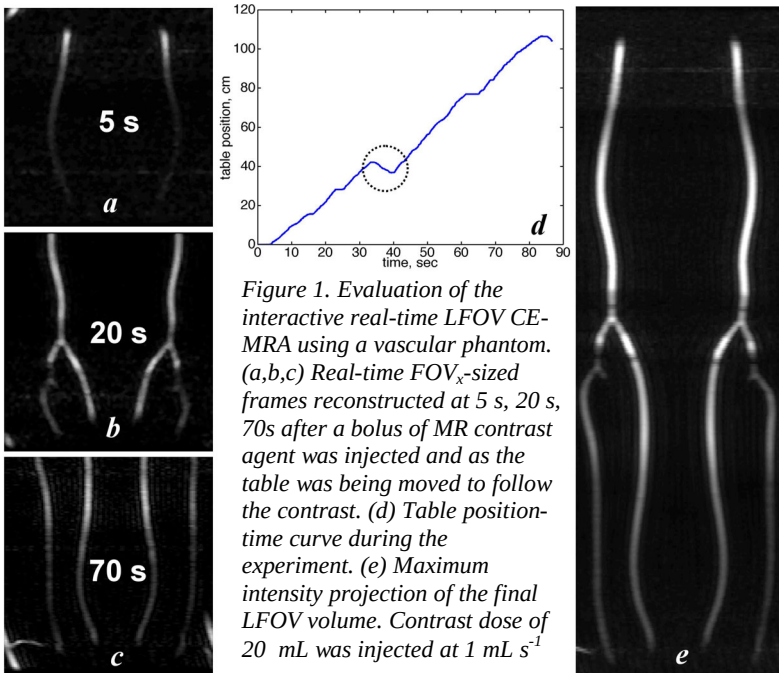

Figure 1. Evaluation of the interactive real-time LFOV CE-MRA using a vascular phantom. (a,b,c) Real-time FOV_x-sized frames reconstructed at 5 s, 20 s, 70s after a bolus of MR contrast agent was injected and as the table was being moved to follow the contrast. (d) Table position-time curve during the experiment. (e) Maximum intensity projection of the final LFOV volume. Contrast dose of 20 mL was injected at 1 mL s^{-1}

Discussion and Conclusions

In interactive LFOV MR imaging, the translation of the table is not constant (Fig. 1d) and can therefore match the specific contrast dynamics in regions of pathology. We implemented this technique and have shown its ability to perform a rapid and patient-friendly examination of the peripheral vasculature. The current implementation allows individual acquisitions to be interactively customized to the anatomic requirements. Initial arteriograms were also obtained from a healthy volunteer, although the contrast bolus was not fully visualized in the real-time images. We anticipate that optimization of the prototype imaging system and the scanning parameters would allow effective real-time contrast monitoring in humans and thus improve image quality. Efforts in this area are ongoing.

References

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