High Temporal & Spatial Resolution 3D Spiral MRA

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Introduction:

For contrast enhanced MRA, time resolved acquisitions provide advantages including the elimination of the need hence the failure of bolus timing, the reduction of venous contamination and the visualization of flow dynamics. The 2D MRDSA technique is playing a valuable role in clinical peripheral MRA (1), however, it is limited in projection views. The 3D PR TRICKS technique overcomes this limitation by employing undersampling and viewsharing to generate time resolved 3D MRA (2), however, it still takes a long time to acquire one complete volume and PR sampling is not SNR efficient. Spiral sampling has a much higher SNR efficiency and a much shorter scan time compared to PR sampling (3, 4). Recently spiral sampling was applied to contrast enhanced MRA with encouraging success (5). Here we improve upon spiral 3D MRA by introducing better off-resonance correction and high temporal resolution.

Methods:

A 3D stack-of-spiral sequence with variable density was implemented on a 1.5T GE scanner (Figs.1a&b). Typical imaging parameters were: 30 cm FOV, 1.1/11.7 msec TE/TR, 60 flip, 24 interleaves, 2640 pts/interleaf, n_z=32 or 20(0.625 partial k_z), 8.9sec or 5.8 sec scan time. For off-resonance correction, low resolution inhomogeneity field maps were acquired at the beginning and the end of data acquisition (2 sec), and the frequency segmented reconstruction algorithm was employed (10 frequency bins) (6). View sharing and sliding window were incorporated into data acquisition and image reconstruction (Fig.1c). Every n^{th} interleaf was updated for a frame time = (scan time)/n, i.e., the interleaf index k_i updating schedule was k_i = (n*t)%24 + frame #, here t = time/(TR*n_z) and frame # = [(n*t)/24]. For example, when n=4, interleaves of all n_z phase encodings were updated in groups in the following order: [0,4,8,12,16,20], [1,5,9,13,17,21]… This time resolved 3D spiral contrast enhanced MRA sequence was applied to 3 volunteers and 10 patients for imaging the lower extremity, the abdomen and the head/neck.

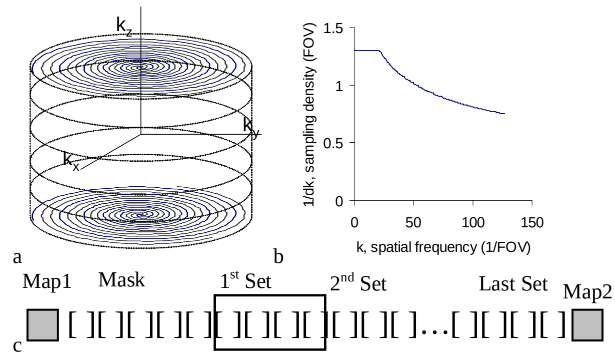

Fig.1. a) 3D stack spiral trajectories with a variable density described in b). c) Imaging protocol when n=4. 2 shaded blocks are field maps for inhomogeneity correction. Each bracket represents a group of 6= 24/4 interleaves. The dark box represents the sliding window, which contains a full k-space data set.

Results:

Off resonance correction was found to be essential to reduce inhomogeneity blurring. The frequency segmented correction with acquired field maps was 5 times faster and more accurate than the previous manual imaginary-minimization method (5). 5-8 cc Gadolinium injection at 1-2 cc/sec was used in this study. Targeted arteries were well visualized. Example images are illustrated in Fig.2.

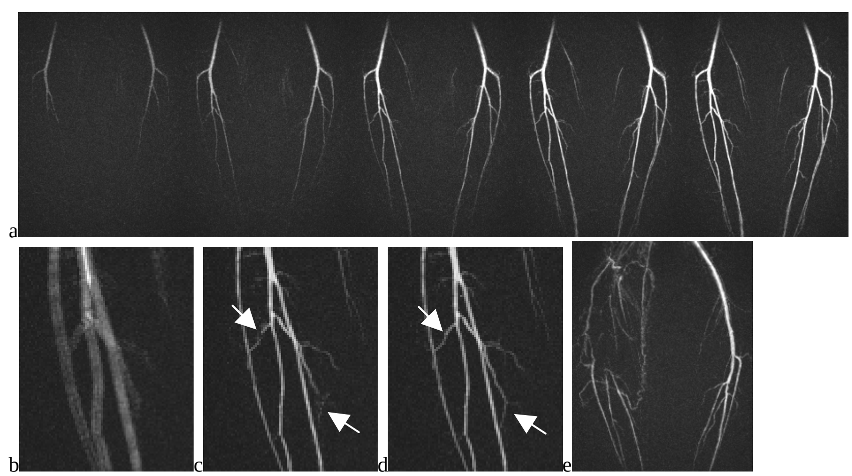

Fig.2.a) First five frames (frontal MIP, 2 sec/frame) from a subject demonstrating contrast arrival in tibial trifurcation. b) Image without correction c) Image corrected with imaginary-minimization method d) Image corrected with acquired a field map e) Image (frontal MIP in peak arterial phase) from a patient's right popliteal occlusion

Discussion:

Our preliminary data demonstrate that high spatial resolution and high temporal resolution time resolved 3D spiral MRA can be easily and consistently performed. The high SNR efficiency and short acquisition time of spiral sampling allows contrast enhanced MRA to be acquired using a small, 6ml Gd dose. Currently the large amount of data requires a long time (~ 1 hr) to complete image reconstruction. This practical issue may be addressed with parallel computing over multiple processors. There is residual blurring near the edge of FOV, which may be corrected for by taking into account of gradient warping.

Reference:

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