Time-Resolved MRA using Radial Multi-Echo Sequence and Sliding Window Reconstruction

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Introduction:

There have been many attempts to increase the temporal resolution of time-resolved MRA, including sliding window reconstruction (1-2), TRICKS (3), and HYPR (4). Although these techniques achieve high frame rates, each frame still contains data acquired over a long temporal window, typically longer than 10 seconds. In other words, the frames have long temporal footprints.

We introduce a technique to decrease the actual acquisition time to decrease the temporal footprint and achieve true acceleration for time-resolved MRA by taking multiple echoes per TR, acquiring a full 3D volume in 7 seconds without parallel imaging. Combined with radial sliding window reconstruction, we obtained time resolved MRA of frame rates comparable to clinical X-Ray DSA, with complete separation of arterial and venous phases. The technique has been verified in flow phantoms and volunteers and patients in vivo.

Methods:

Radial in-plane and Cartesian through-plane trajectory were used (“stack of stars”). Spoiled gradient-echo sequence was used with multiple bipolar readout gradients. Z-encoding blips were used between bipolar gradients to acquire each partition in a manner similar to the segmented EPI. Additional correction blips were played in the readout direction for gradient delay corrections.

Figure 1 illustrates the data acquisition scheme for the case with 3 echoes per TR.

For in vivo imaging, 5 echoes were acquired during each TR, resulting in TR=7.3ms (echo spacing=0.9ms). Other imaging parameters were: FOV=220x220mm, Nslice=30 (thickness 3mm), Nproject=192, Nreadout=192. Total acquisition time for one 3D volume was 7 sec, about 50% of the time required with single echo sequence.

Healthy volunteers were scanned with a Siemens 3T Trio scanner (Siemens Medical Solutions, Erlangen, Germany) with the multi-echo sequence and the conventional single-echo sequence for comparison. ROIs were drawn on the arteries and veins to compare the temporal profiles of the contrast enhancement and the signal-to-noise ratio.

Results:

Figure 2 shows a comparison of the sagittal maximum intensity projections (MIPs) reconstructed from the multi-echo sequence and the single-echo sequence on two different volunteers. The multi-echo sequence resulted in images (Figure 2a) with signal-to-noise ratio and a spatial resolution comparable to the single-echo sequence with similar parameters (Figure 2b) while taking 50% of the time required to acquire a 3D volume using the single-echo sequence. The corresponding temporal profiles on the right of the images from arterial and venous ROIs (red and blue circles) show that the multi-echo sequence has superior temporal information characterized by sharper and better separated arterial and venous signal profiles.

Discussion:

Using the multi-echo sequence for high speed time-resolved MRA was shown to be feasible. Using this technique, a 3D volume can be acquired twice as fast without parallel imaging compared to a standard MRA sequence.

References

Figure 1: Radial acquisition scheme with 1 echo per TR (left) and 3 echoes per TR(right). The multi-echo sequence can achieve acceleration factor of 2 compared to standard MRA sequence.

Figure 2: Comparison of multi-echo(a) and single-echo(b) MRA sequence. While image quality of the multi-echo image is comparable to the single-echo image, the temporal profile is sharper for the multi-echo sequence.