# 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, $N_{slices}$=30 (thickness 3mm), $N_{projections}$=192, $N_{readout}$=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.

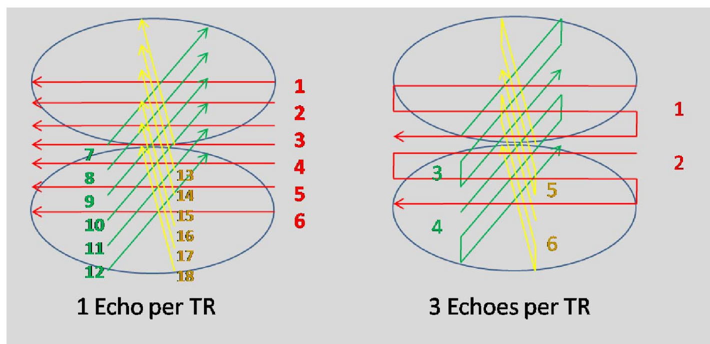


**Figure 1: Radial acquisition scheme with 1 echo per TR (left) and 3 echoes per TR(right).** The multi-echo sequence can achieve acceleration factor of 2 compared to standard MRA sequence.

## 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.

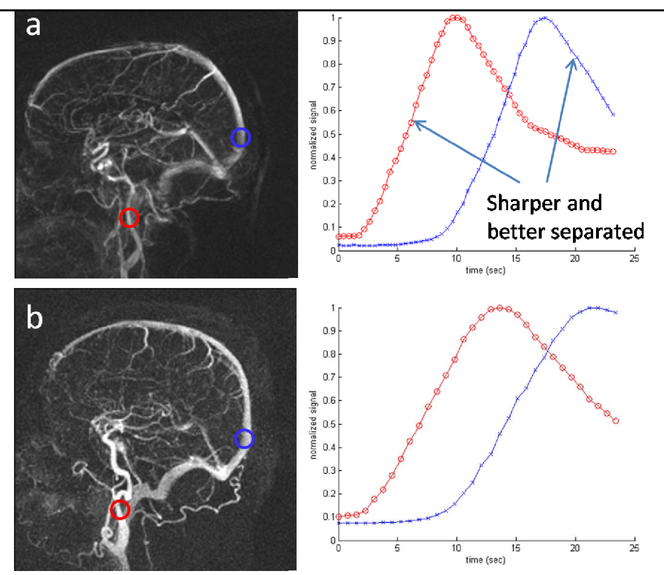


**Figure 2: Comparison of multi-echo(a) and single-echo(b) MRA sequence**. While image quality of the multi-echo image is comparable to the single-echo image, the temporal profile is sharper for the multi-echo sequence.

## References

1. Riederer et al. Magn Reson Med 1988.
2. Cashen et al. Magn Reson Med 2007.
3. Korosec et al. Magn Reson Med 1996.
4. Mistretta et al. Magn Reson Med 2006.