Accelerated Time Resolved Inflow with 3D Multi-Echo Radial Trajectories

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Introduction: Arterial spin labeling (ASL) sequences which utilize tagging schemes to images the flow of blood have emerged as effective techniques for the non-contrast angiography; however, these techniques typically suffer from long acquisition times, sensitivity to tag delay parameters, and uncertain performance in cases of complex flow [1-3]. To mitigate these errors, we have previously demonstrated the preliminary feasibility of a highly accelerated, dynamic inflow imaging utilizing efficient, short TR 3D radial bSSFP sequences [4]. In this work, we investigate various techniques for further improvements in image quality and acceleration and provide demonstration capabilities in an animal model..

Methods: We have implemented an ECG-triggered, inversion-recovery prepared, bSSFP, 3D sequence capable of imaging with multi-echo 3D radial trajectories [5]. Dynamic inflow images are obtains by subtracting an inversion time (TI) resolved acquisition with a non-selective from an acquis
ition with an inversion slab just acquiring the image volume as shown in Figure 1. Radial sampling is performed in an interleaved fashion such that images can be reconstructed at low temporal resolution with limited undersampling or at high temporal with increased undersampling or reduced spatial resolution. With institution board approval, time resolved inflow images were acquired on a clinical 1.5T scanner (Signa HDxGE Healthcare; Waukesha, WI) in five Healthy human volunteers and two Canine aneurysm models. Common imaging parameters include: 4-half echo radial trajectory, FOV=22x22x14cm^3 , flip angle = 45º. In healthy, volunteers an optimized sequence with adiabatic VERSE inversion pulse, iterative SENSE reconstruction, ordering scheme that minimizes k-space jumps and pairs k-space angles, and a high time bandwidth RF was compared to our initial implementation with a standard SLR inversion pulse, paired bit-reverse ordering, standard gridding reconstruction, paired bit reverse projection ordering, and low time bandwidth RF pulse. The optimized protocol achieved 0.7mm isotropic resolution in an imaging time of 3:30 while the previous non-optimized protocol achieved 1mm isotropic spatial resolution in 6:00. Canine aneurysm models were imaging using only the optimized protocol.

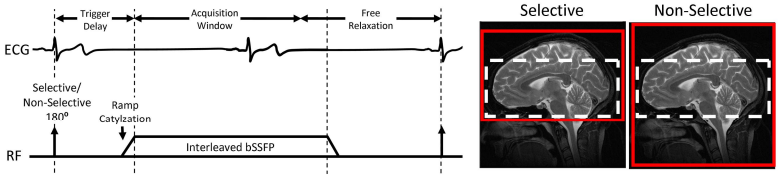

Figure 1. *Imaging timing diagram (left) and inversion slab locations (right) for intracranial inflow bSSFP with a FAIR tagging scheme. Solid red lines indicate the inversion volumes and solid white lines the imaging volume.*

Results: Figure 2 shows representative comparison of the composite images of the sequences. Both sequences show all major vessels; however, the optimized protocol shows significantly better visualization of small arteries, improved background suppression, and signal intensity. Figure 3, shows dynamic time resolved angiography images acquired in the canine aneurysm model. High temporal resolution dynamic images show visualization of rapid intra-arterial filling effects; which are not possible to visualize with contrast enhanced MRA due to bolus dispersion. The composite angiogram proves excellent visualization of both the main aneurysms and a thrombosed side wall aneurysm (arrow Figure 3)..

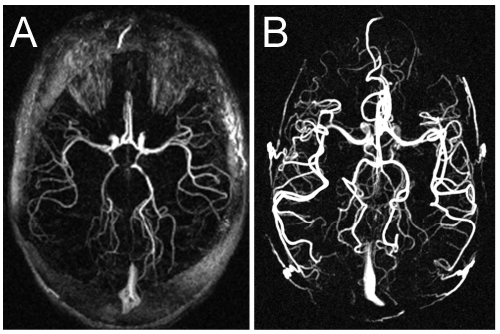

Figure 2. *Comparison of intracranial composite images obtained with a non-optimal, longer sequence (A) and shorter optimized sequence (B). Improved background suppression, better vessel conspicuity, and higher spatial resolution (1.0mm vs. 0.7mm isotropic) are achieved.*

Conclusion: Time resolved inflow with 3D radial trajectories provides imaging of arterial filling without bolus dispersion or injection of a contrast agent. The utilization of highly accelerated radial trajectories allows the acquisition of high resolution images in clinically feasible scan times with minimized artifacts from flow and off-resonance banding.

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References: [1]. Bi et al. Proc MRA Club 08 #31 [2] Chen et al. ISMRM 02 #1357 [3] Miyazaki et al. Radiology 248(1):20. [4] Johnson et al MRA Club 09 #25 [5]. Lu et al. MRM 53:692-699

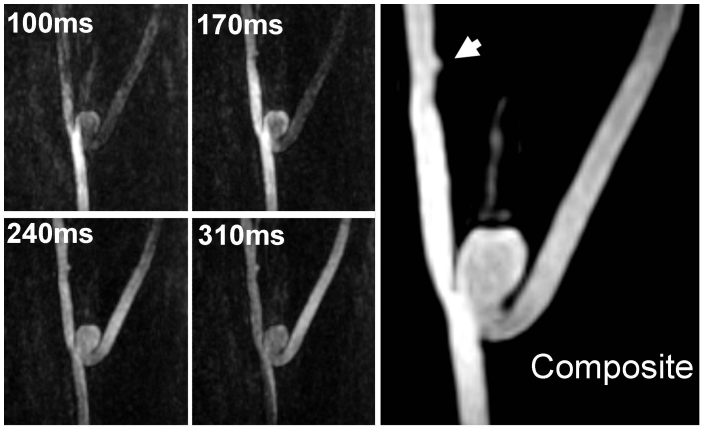

Figure 3. *Dynamic limited MIPs of 3D angiograms reconstructed every 35ms (every other frame shown) and a time averaged composite of a surgically created venous pouch aneurysms model. Time after inversion if Time frames allow visualization of the asymmetric filling while the composite provides high resolution morphology. All data was collected in 3:30min with isotropic spatial resolution.*