Visualizing Flow Using MR Tagging and FIESTA Imaging

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Introduction: MR tagging has previously been demonstrated as a means for visualizing and quantifying flows in fluids[1,2]. These techniques have relied on constant or periodic flow patterns so that images can be built up over long periods of time through repeated applications of the tagging pulse and gating the acquisition to the same period in the flow. These repeated acquisitions are necessary since the tags have a limited lifetime due to signal relaxation and flow-induced dephasing. In addition these techniques were only demonstrated in cases of very slow flows (3-12 mm/sec). Recently it has been demonstrated that myocardial tagging of tissue can be improved using a steady-state FIESTA acquisition due to the different relaxation characteristics (i.e. the long approach to steady-state) in these acquisitions[3,4,5]. This same benefit should also apply to tagging of fluid flow. In addition, we hypothesize that there will be additional benefits of using a FIESTA acquisition for visualizing fluid flow. First, the nature of steady-state acquisitions is such that spin coherence is maintained for much longer and thus the coherence of tagged signal in the presence of flow should be maintained for a longer period of time in a FIESTA acquisition. Secondly, the persistence of tagged signal should be even greater in fluids than in myocardial tissue due to the longer relaxation times. Finally, the rapid nature of FIESTA acquisitions in combination with a longer tag persistence may make it possible to use an ungated, multi-phase FIESTA acquisition to visualize non-periodic or non-constant flows including those with high velocities.

Methods: A FIESTA imaging sequence was modified to play out simple slice-selective 90-degree tagging pulse(s) prior to the standard imaging acquisition. Phantom imaging was performed in a cylindrical water phantom. Fluid motion was induced by moving a stick in linear or circular patterns after the initiation of imaging. In the phantom experiment two orthogonal tags were applied to improve flow visualization. In vivo imaging was performed by applying a single tagging pulse 1) through the spinal column near the base of the brain to visualize CSF motion and 2) through the abdominal IVC to visualize venous flow. In the phantom studies imaging was performed ungated at 128x128 resolution over 20x10cm field of view and 0.5 NEX, corresponding to 200ms temporal resolution. Temporal resolutions were also doubled using an ASSET factor of 2. In CSF, an ungated 128x128 acquisition matrix over 24x24cm was acquired with an ASSET factor of 2 and 0.5 NEX for a temporal resolution of 160ms. In the IVC a gated CINE acquisition using a 256x256 matrix over 35cm with 20 cardiac phases reconstructed. In this case the tag was applied at the beginning of each heartbeat.

Results: Sample images from different time points for the 128x128 phantom data are shown in Figure 1. Figure 2 shows source images and their difference from the last time point image in a zoomed region illustrating the CSF motion in vivo. Figure 3 also shows source and difference images of flow in the IVC.

Conclusion: MR tagging with FIESTA imaging makes it possible to visualize flow patterns in regions of complex, non-periodic, non-constant, rapid flows.

References: 1) Weis et al., MRI, 1996. 2) Tyszka et al., JMR, 1992. 3)Herzka et al., MRM, 2003. 4) Zwanenburg et al., MRM, 2003. 5) Markl et al., Radiology, 2004

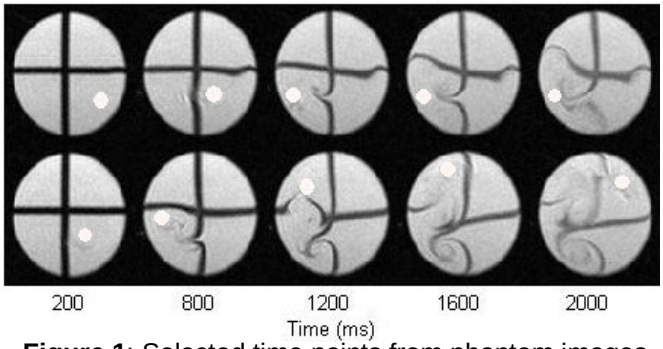

Figure 1: Selected time points from phantom images for left to right motion (top) and clock wise motion (bottom) of a stir-stick (circles).

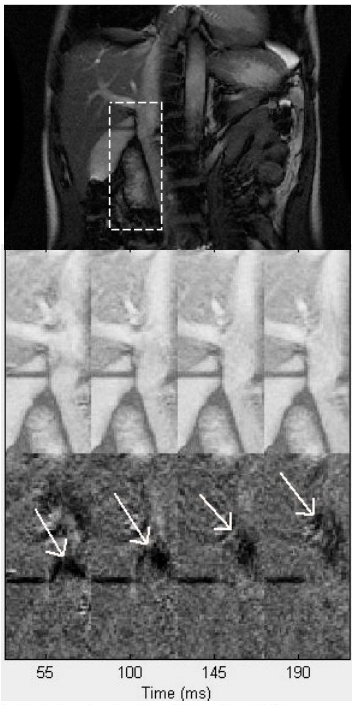

Figure 3: Reference image (top) indicating the zoomed in region (dashed rectangle). Sample unsubtracted (middle row) and subtracted (bottom row) images from selected time points from a gated acquisition showing tag progression (arrows) in the IVC.

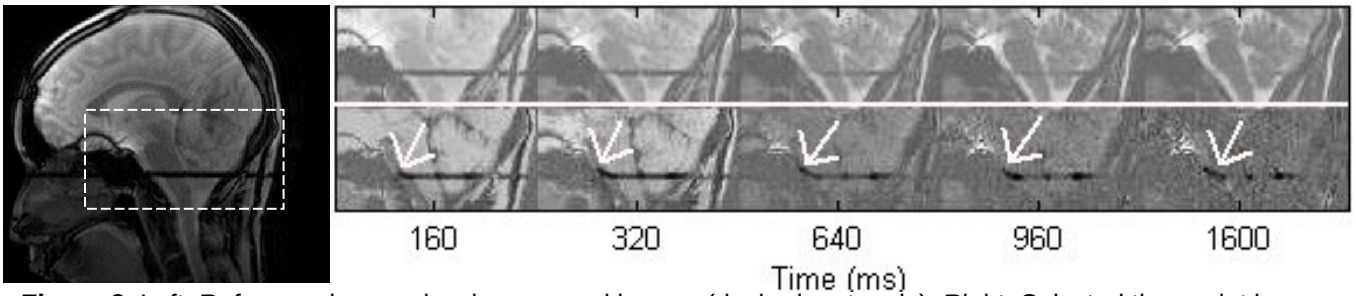

Figure 2: Left: Reference image showing zoomed in area (dashed rectangle). Right: Selected time point images showing motion of CSF in unsubtracted (top row) and subtracted (bottom row) images. The pulsatile motion of CSF can be seen (arrows).