Making MR-Invisible Devices Visible for Vascular Interventional MRI

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Introduction: Interventional MRI is playing an increasingly important role for guiding endovascular procedures. MR-compatible devices for these procedures are often designed to be MR-invisible or MR-visible by the incorporation of passive markers or active coil tracking systems with the negative impact of increasing the device diameter. Recently, techniques have been proposed to create positive or white marker imaging from the susceptibility artifacts created by superparamagnetic iron oxide (SPIO) particles (Coristine et al. (2004); Cunningham et al. (2004)). Using a new imaging methodology, called **I**nversion **R**ecovery **ON**-resonance (IRON), we have developed a method to create MR-visible bright images of devices such as stents and coils.

Methods: Using the IRON pulse sequence consists of: 1.) two non-selective inversion recovery (IR) pulses separated by an interval TI to null fat ; 2.) a spatial presaturation (SPIR) rf pulse centered on the water frequency to suppress all signal except the protons locally dephased by field inhomogeneities created by non-diamagnetic objects; and 3.) turbo spin echo image acquisition. Thus, the resultant image consists of bright signal from the device and suppression of all surrounding tissue including fat.

To test the feasibility of imaging vascular devices, a saline phantom containing a drug-eluting stainless steel stent (Cypher, Johnson & Johnson), a deployed and undeployed MR-compatible nitinol stent, and an MR-compatible imaging guidewire were imaged on a 1.5T clinical MR scanner (Intera, Philips, Netherlands) using IRON imaging. Two-dimensional slices and 3D volumes of the devices were acquired with and without fat suppression using the IRON pulse sequence with image parameters of: 180 mm FOV; 2000 ms TR; 7 ms TE; 0.7 x 0.7 x 0.7-5 mm^3 voxel; 2 NSA; and 24 ETL. The IRON imaging was adapted to a real-time GRASE (Feinberg and Oshio (1991))sequence for interactive imaging (180 mm FOV; 158 ms acquisition time; 5.8 ms TE; 4 x 4 x 5 mm^3 voxel; EPI factor of 3; and turbo factor of 11) of stents as might be used for deployment under MR fluoroscopy.

Results and Discussion: An unexpanded nitinol stent and stainless steel stent were clearly visualized with the IRON pulse sequence (Fig 1). Inversion recovery can be used to null the signal from fat (Fig 1B &C) without affecting the IRON signal enhancement. The size of the signal enhancement can be altered by changing the bandwidth of the on-resonance SPIR pulse (Fig 1). The MR-compatible imaging guidewire (when disconnected from the scanner), however, did not create a hyperintense signal. The struts of the expanded nitinol stent were clearly visualized when a three dimensional volume was acquired (Fig 2). The motion of the stainless steel and nitinol stents could both be tracked using the real-time imaging sequence (Fig 3).

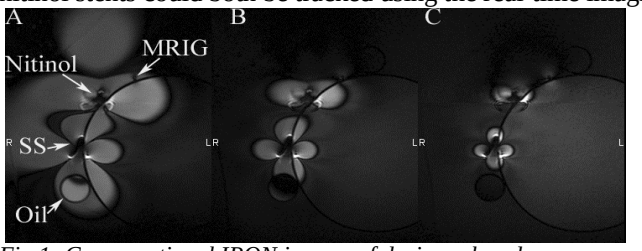

Fig 1: Cross-sectional IRON images of devices placed on a copper sulfate bottle in a saline bath. (A) 340 Hz BW IRON without fat sat (FS) shows large hyperintesity with the drug-eluting stainless steel stent (SS) & nitinol stent (Nitinol) but no signal enhancement for the MR imaging guidewire (MRIG); (B) 160 Hz BW IRON with FS shows suppression of a 10cc syringe of baby oil and more well defined signal enhancement; (C) 100 Hz BW IRON with FS shows further refinement of signal enhancement from stents.

Conclusion: Nitinol stents are typically used to minimize MR imaging artifacts which makes device placement under MR fluoroscopy difficult. IRON imaging has the potential to enable the positive contrast enhancement for visualization of both nitinol and stainless steel devices without the need for passive markers or tracking coil electronics. Thus, IRON imaging presents a method for interventional MR imaging of endovascular devices as well as SPIO labeled cellular therapeutics.

References:

Coristine AJ et al. (2004). Positive contrast labelling of SPIO loaded cells in cell samples and spinal cord injury. Proc ISMRM, Kyoto, Japan.

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Feinberg DA, Oshio K (1991) GRASE (gradient- and spin-echo) MR imaging: a new fast clinical imaging technique. Radiology **181**(2): 597-602.

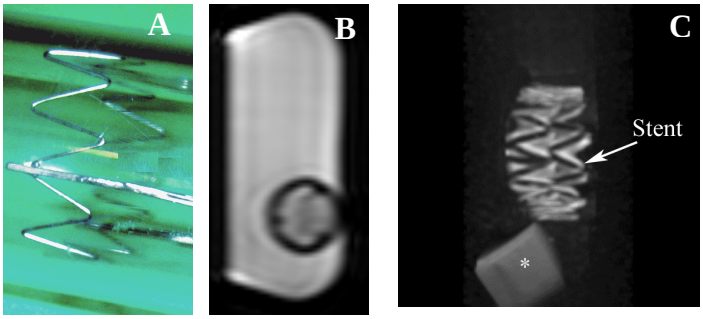

Fig 2: Digital image (A) of expanded nitinol stent, which creates small signal void in axial projection in a scout fast gradient echo image (B). However, 3D projection of IRON image shows signal enhancement around the Z struts of the stent (C) as well at air-water interface of the flask (*).

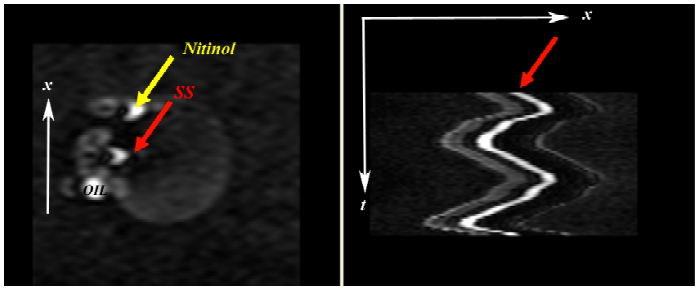

Fig 3: Single GRASE image (left) of phantom from Fig 1 which is moved back and forth in x direction. Trajectory in x direction of stainless steel stent (red arrow) over time (t) is shown on right.