Positive Contrast Passive Catheter Tracking and Endovascular Device Visualization using IRON MRI

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Introduction: Interest in developing interventional MRI for guiding endovascular procedures has grown in recent years with the advancement of cardiovascular MRI and the desire to minimize patient radiation exposure. Particularly, several groups and companies have worked on developing passive and active catheter tracking systems (PCT and ACT, respectively) and have modified many endovascular devices to be MR-compatible. Typically, PCT methods have shown relatively poor results for device localization due to low signal-to-noise ratio (SNR). Visualization is further diminished when using MR-compatible endovascular devices. ACT systems overcome these SNR problems by employing specially designed catheters equipped with coils that transmit signal to their own dedicated receiver channel. However, adoption of ACT systems has been limited by concerns about device heating and size.

Recently, positive contrast methods based on off-resonance signal imaging have been explored for PCT [1,2]. In particular, our group has developed the Inversion Recovery with ON-resonant (IRON) water suppression method which selectively isolates and enhances the off-resonant signal induced by non-diamagnetic objects such as conventional catheters and endovascular devices. We have previously demonstrated in vitro studies showing the ability of IRON MRI to track MR-compatible endovascular devices with positive signal enhancement and to visualize these devices with high resolution. In this study, we present preliminary ***in vivo*** work toward the development of passive catheter tracking and endovascular device visualization using signal-enhanced IRON MRI.

Methods: All experiments were performed in our new integrated 3T MRI/X-ray Angiography suite (Achieva/Pulsera, Philips Medical Systems). Mongrel dogs (n=2) were anesthetized, and an 8Fr introducer sheath was placed in the femoral artery. Under x-ray fluoroscopy, a stainless steel guidewire and balloon-expandable stainless steel stent (SSS; 7mmx15mm, Palmaz Genesis Transhepatic Biliary Stent, Cordis Corp.) was advanced from the femoral artery to the iliac bifurcation and an x-ray angiogram was obtained. The stainless steel guidewire was then removed leaving the balloon expandable stent. The animal was transferred from the x-ray area of the suite to the MR scanner. Prior to IRON imaging, 3D MR angiography (SSFP time-of-flight; TR/TE=6.4/3.2ms, flip angle (FA)=75°, resolution=0.58x0.58x3mm^3) was performed to provide a roadmap for iliac artery catheterization. The conventional SSS was then advanced from the femoral artery into the ipsilateral iliac artery using a real-time Gradient and Spin Echo (GRASE) acquisition (TR/TE=190/6ms, FA=90°, resolution=2.7x2.7x5mm^3, Echo train length (ETL)=16) with an IRON pre-pulse (IRON angle=95°, IRON angle bandwidth=140Hz) and spectrally-selective fat suppression. Stent deployment was monitored using the real-time GRASE with IRON sequence. After deployment, high resolution 2D (resolution=0.68x0.68x5mm^3) and 3D (resolution=0.45x0.45x1mm^3) IRON fast spin echo (FSE; TR/TE=1500/8.8ms, ETL=22) and gradient echo (GRE; TR/TE=10.2/5.0ms, ETL=24) images were acquired. Maximum intensity projections (MIP) were created from the 3D MRA and registered with the 2D IRON GRASE images.

Results and Discussion: MIPs provided a high quality roadmap (Fig 1A) for successful MR-guided placement of a SSS in the iliac artery using IRON with a real-time GRASE acquisition. Blood flow through the external iliac artery was not visible by MRA following stent deployment due to the artifact generated by the time-of-flight sequence. Signal enhancement from the stent was clearly seen in the real-time IRON images (Fig 1B) and was used to guide and position the catheter in the iliac artery. High-resolution IRON images (Fig 1C) showed hyperintense signal around the vessel corresponding to the stent deployment location. In one dog, the stent was undersized for the target vessel and real-time IRON imaging showed antegrade movement of the stent following deployment.

Conclusions: IRON can be combined with real-time MR imaging to passively track catheter motion in endovascular procedures with conventional stents. Furthermore, high resolution IRON imaging can be used to visualize deployed endovascular devices *in vivo*. The IRON technique provides a means of performing interventional MR imaging without the need for passive markers or active coil systems.

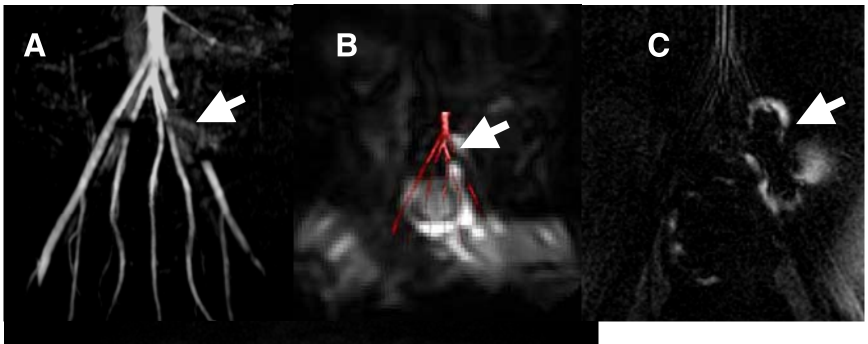

Fig 1. (A) Maximum intensity projection (MIP) reconstructed from 3D time-of-flight (TOF) MR angiographic (MRA) images of the peripheral vessels in a dog. The arrow identifies the stent location as a loss of signal which is expected in TOF sequences. (B) The MIP is overlayed (in red) on a single frame from a real-time IRON GRASE acquisition. A hyperintense signal is seen surrounding the location of the stent on the IRON images which corresponds with the signal loss in the MIP. (C) High-resolution coronal IRON image post-stent deployment clearly shows hyperintense signal around the stent in the iliac artery.

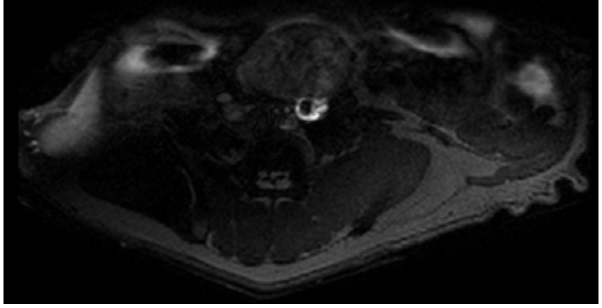

Fig 2. Axial slice from a 3D IRON image set showing hyperintense signal in the left external iliac artery associated with the placement of a stainless steel stent.

References:
1. Seppenwoolde et al. MRM 2003.
2. Kraitchman et al. ISMRM 2005.