Intravascular 3.0T MR Imaging: A feasibility Study in Swine

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Introduction: Magnetic resonance imaging (MRI) is a useful imaging tool for visualization of vessel walls and characterization of atherosclerotic lesions, providing high resolution and multiple imaging planes with no risk of radiation. The use of MR technology is, however, limited in imaging of deep-seated arteries, primarily due to insufficient signal-to-noise ratio (SNR) with a surface coil. To solve this problem, scientists have developed intravascular MRI techniques that place intravascular coils, such as a MR imaging-guidewire (MRIG), into deep-seated arteries to create high SNR images of target vessel walls/plaques[1,2]. To date, most of the reported studies on intravascular MRI have been performed in 1.5T MR scanners. The aim of this study was to validate the feasibility of generating intravascular 3T MRI of deep-seated arteries of near-human-sized swine by using a 3T-MR compatible MRIG.

Materials and methods: A series of in vitro experiments were designed to (i) test the functionality of a 3T-MR compatible MRIG; and (ii) compare the SNRs generated by the MRIG and surface coils. We produced a 0.032-inch MRIG that was made of a Nitinol coaxial cable with an extended 3.2-cm inner conductor (Fig. 1A). The tip of the MRIG was refined with a solenoid spring to facilitate the smooth advancement of the MRIG into the vessels and thereby avoid vessel injury during the endovascular manipulations. For measuring SNR of the MRIG, we placed the MRIG into the center of a water bath, while for measuring SNR of surface coils, we placed two flex-L coils, each at the top and bottom of the water bath. The MRIG was connected to a 3T Philips MR scanner through a matching/tuning/decoupling circuit, which operated in a receive-only mode. The MR parameters included an improved Motion Sensitized Driven Equilibrium (iMSDE) sequence with TR/TE at 5000ms/40ms. Then, the signal intensities (SI) of each pixel were picked up along a straight line paralleled to the MRIG. The SNRs were calculated by Matlab 2009a. To test the functionality of the MRIG for generating 3T MRI, we built a phantom using a plastic box, through which a plastic tube was installed horizontally to mimic a "vessel". We then placed the MRIG into the middle portion of the plastic "vessel" of the phantom filled with water (Fig. 1B). The MR imaging was performed by using a turbo spin echo (TSE) sequence for: (i) axial T2-weighted image (T2WI) with TR/TE at 3000ms/80ms; and (ii) coronal T2WI with TR/TE at 2100ms/91.1ms.

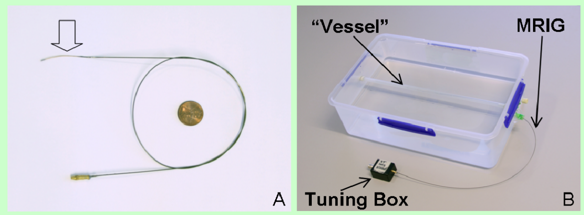

Fig 1. (A) The 0.032-inch MRIG with its extended inner conductor (arrow). (B) Setting up for in vitro MRI.

To validate the feasibility of intravascular 3T MRI, we then performed in vivo experiments with six domestic pigs. Through a surgical cut-down or percutaneous puncture guided by ultrasound, a 4F or 6F introducer was placed into ten of the femoral veins of the six pigs. We first acquired MRI of the iliac arteries using the surface coils, and then acquired a transvenous MRI of the parallel-run iliofemoral arteries using the MRIG. The MR parameters included iMSDE sequence for: (i) axial T2WI using the surface coils with TR/TE at 4500-5000ms/40ms; and (ii) axial T2WI using the MRIG with TR/TE at 4500-5000ms/40ms. SIs of arterial walls were measured on the axial images and then calculated by the formula $SI_{wall} = (SI_{total\ vessel} \times Area_{total} - SI_{lumen} \times Area_{lumen}) / (Area_{total\ vessel} - Area_{lumen})$. In addition, we also recorded the standard deviation of background noise and corrected with a factor 0.655 for MRIG and 0.682 for surface coils, and then calculated the SNR for each vessel segment. By using a paired Student t-test, we subsequently compared the average SNRs of arterial walls between surface coil-MRI and MRIG-MRI.

Results: Of the in vitro experiments, the MRIG generated much higher SNRs than surface coils (Fig 2A). A peak SNR was appeared near the conjunction (68.5mm) of the MRIG. The MRIG generated high resolution images, which clearly delineated the plastic "vessel" wall (low signal intensity) and water (high signal intensity)(Fig. 2B). Of the in vivo experiment, all of the animals survived during the entire experiments. Intravenous MRI using the MRIG displayed the iliofemoral arterial walls more clearly than that using the surface coils (Fig. 3). The average SNR of iliofemoral arterial wall images using the MRIG was significant higher than that using the surface coils (49.92±22.77 vs. 11.59±10.07, $P<0.01$).

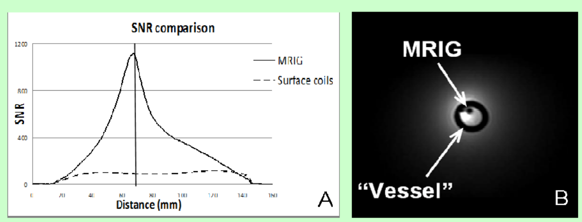

Fig. 2. The SNRs of the MRIG and surface coils (A). In vitro MRI of the "vessels" at axial view (B).

Conclusions: This study has validated the feasibility of generating an intravascular 3T MRI of iliofemoral arteries in near-human-sized pigs, which should establish the ground work for translating this technique to clinical practice.

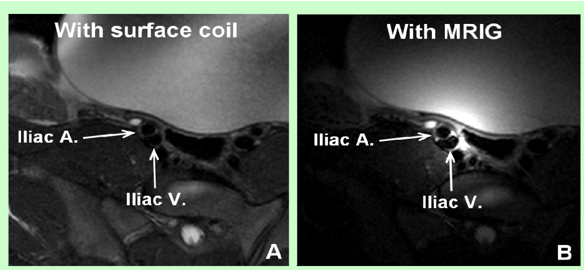

Fig. 3. In vivo MRI with the surface coils (A) and the MRIG (B).

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References: [1] Brushett C, et al. JMRI 2008;27:246.
[2] Larose E, et al. Circulation 2005;112:2324.