In Vivo Assessment of Renal Artery Embolization Using a Magnetically Assisted Remote Controlled (MARC) Catheter

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Target Audience: Interventional MRI community

Purpose: A specialized magnetically assisted remote controlled (MARC) catheter was developed [1] to enhance navigation capabilities in endovascular interventional procedures using MR image guidance. The MARC catheter has a coil at the tip that creates a magnetic moment when excited. The magnetic moment tries to align with the direction of B_0 causing the tip of the catheter to deflect. The purpose of this study was to assess the *in vivo* performance of the MARC catheter system for renal artery embolization in a swine model. Performance parameters such as navigation time, change in renal artery flow, and change in renal perfusion were compared between interventions performed using MR and X-ray guidance.

Methods: The MARC catheter prototype used in this study has a saddle shaped micro-coil embedded on a 1.2 mm diameter alumina tip (Fig. 1). The micro-coil tip was fabricated using a laser lithography process [2], and was attached to a custom 1.2 mm diameter microcatheter (Penumbra Inc., Alameda, CA) using medical grade polyester heat shrink tubing (Advanced Polymers, Salem, NH). Electrical connections to the micro-coil were made using a pair of 0.125 mm diameter copper wires embedded in the catheter wall. Renal embolization (100 – 300 uM particles) was performed on a series of three animals (40 – 45 kg) using a hybrid imaging suite consisting of a 1.5T clinical MR scanner (Phillips Achieva) and a C-arm DSA system (Phillips Integris V5000). The workflow (Fig. 2) consisted of switching between the X-ray and MR suites using a floating tabletop. MR imaging was performed using a 4-channel surface receive coil with real time navigation performed using a bSSFP sequence (T_E = 1.7 ms, T_R = 4.2 ms, flip = 60, FOV = 20x20 cm, frame rate = 1.3 fps). After obtaining access to the appropriate renal artery the embolic beads suspended in gadolinium contrast agent (Magnevist) were delivered while obtaining a MR angiogram (T_E = 1.4 ms, T_R = 4.3 ms, flip angle = 30, FOV = 20x20 cm, frame rate = 0.3 fps). Embolization of the contralateral kidney was performed under X-Ray guidance for comparison. Flow rates for both kidneys were measured using a velocity encoded scan (T_E = 5.0 ms, T_R = 8.0 ms, flip angle = 15, FOV = 16x16 cm, 5 mm slice), while perfusion rates were measured using a 4D THRIVE sequence (T_E = 2.0 ms, T_R = 4.0 ms, flip angle = 10, FOV = 28x28 cm, 4 mm slices, 30 slices).

Results: The average time for navigation to the renal artery was 60 ± 22 seconds for X-ray versus 93 ± 56 seconds for MRI (p = 0.40). The average change in renal blood flow (normalized by kidney mass) was 1.9 ± 0.2 mL/min/g for X-ray versus 2.1 ± 0.2 mL/min/g for MRI (p = 0.55). The average change in rate of perfusion was 4.6 ± 0.6 a.u./sec for X-ray versus 4.9 ± 0.8 a.u./sec for MRI (p = 0.64).

Discussion/Conclusions: This study demonstrates feasibility of the proposed renal intervention using the MARC catheter. It is a significant step forward in our pre-clinical model as this is the first intervention model that has been developed for this technology and demonstrates that the current system architecture is compatible with the MR environment. Comparing the performance parameters demonstrates that MR guidance is as effective as X-ray guidance for this particular renal intervention model. Future work will be focused on testing new MARC prototypes that differ in mechanical stiffness.

References:

1. Roberts, T.P., et al., *Remote control of catheter tip deflection: an opportunity for interventional MRI.* Magn Reson Med, 2002. **48**(6): p. 1091-5.
2. Malba, V., et al., *Laser-Lathe Lithography--a Novel Method for Manufacturing Nuclear Magnetic Resonance Microcoils.* Biomedical Microdevices, 2003. **5**(1): p. 21-27.

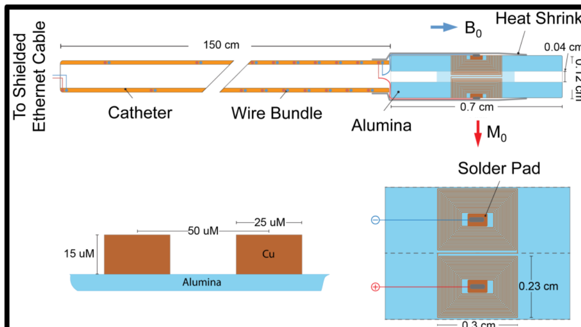

Fig. 1: A) Schematic of the MARC catheter architecture. B) Profile view of copper traces. C) Coil pattern on alumina tip.

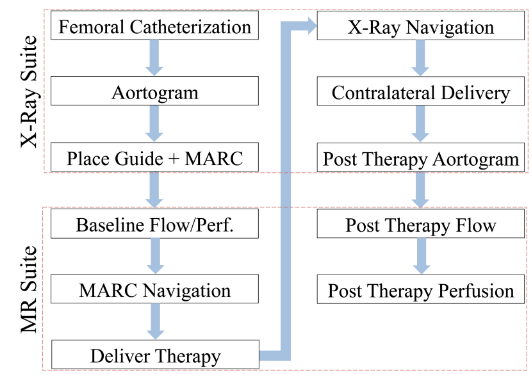

Fig. 2: XMR Suite Workflow

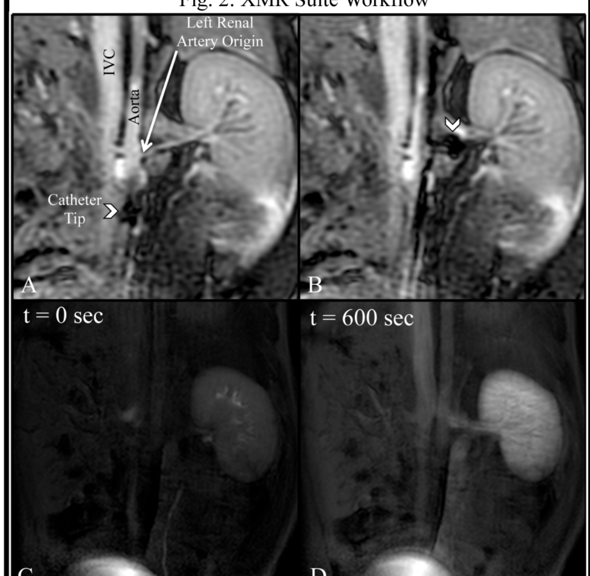

Fig. 3: A) Navigation in Aorta with catheter tip inferior to renal artery origin B) Navigation into origin of left renal artery C) Embolization at 0 seconds D) Embolization at 600 seconds