Intra-Arterial MRA based Roadmapping for Magnetically-Assisted Remote Control Catheter Tracking

Alastair Martin1, Prasheet Lillaney1, Maythem Saeed1, Fabio Settecase2, Lee Evans1, Mark Wilson1, and Steven Hetts1

1Radiology and Biomedical Imaging, UCSF, San Francisco, CA, United States, 2Dept of Medical Imaging, Sunnybrook Health Sciences Centre, Toronto, ON, Canada

Introduction
We have been investigating magnetically-assisted remote control (MARC) endovascular catheters for interventional MRI procedures. MARC catheters contain microcoils on their tips that can be transiently activated by applying DC current [1]. The resulting magnetic moments created by the microcoils generate deflections that enable steering of the catheter into selected vascular structures. These steerable catheters have conductive elements running along their length and produce a magnetic field disturbance around the microcoils and wires when current is applied. While this magnetic field disturbance allows for passive visualization it also obscures the anatomy through which the catheter is being navigated. In this study we developed an alternate tracking approach that capitalizes on arterial access to generate selective intra-arterial angiograms that are used in a “roadmapping” mode to assure that vascular structures are not obscured when catheter deflections are applied. The concept is described and demonstrated in a swine model.

Methods
The technique is based on selective intra-arterial (IA) injections of dilute (1-2mM) gadolinium (Gd) contrast medium (Magnevist,) at the beginning of a dynamic MR angiographic acquisition. The angiogram is a thick slice 2D gradient echo sequence that can be obtained rapidly and requires only brief (~4s) IA infusions (at 1-2cc/s) to highlight the vasculature. The low Gd concentration and short IA angiogram permits exceptionally low contrast doses and makes repeated evaluations practical. The initial angiogram is used as a roadmap that is subtracted from subsequent dynamic acquisitions, similar to conventional DSA practices. Keyhole methods are employed to increase the temporal resolution of the dynamic acquisition above that of the initial angiogram (typically>1fps). Advantages of this approach include the fact that local arterial anatomy is established at the outset and is retained throughout the acquisition period. It also permits very low SAR acquisitions which are necessary when catheters with conductive elements are present to minimize RF heating. Importantly, currents applied for catheter deflection, which produce considerable susceptibility artifact, will not obscure the previously established roadmap. The angiographic sequence is only moderately T1-weighted to allow for passive visualization it also obscures the anatomy through which the catheter is being navigated. In this study we developed an alternate tracking approach that capitalizes on arterial access to generate selective intra-arterial angiograms that are used in a “roadmapping” mode to assure that vascular structures are not obscured when catheter deflections are applied. The concept is described and demonstrated in a swine model.

Results
The angiographic imaging protocol (FOV = 200X162mm, voxel dimensions = 1mm x 1mm x 8mm, TR/TE/α = 8.0ms/1.8ms/20°, BW/pix = 192 Hz, SAR = 0.1 W/kg) was initially acquired in 1.3s while 2mM Gd-based MR contrast was injected at 2cc/s (Fig 1A). Subtraction of all subsequent frames began immediately and a keyhole factor of 60% was employed to achieve a frame rate of 1.33 fps. This balanced our ability to track smaller objects with an acceptable refresh rate. Blood flow rapidly washed out the IA injection (Fig 1B) to reveal the arterial roadmap on subsequent subtracted images (Fig 1, lower row). Activation of the MARC catheter produced a substantial artifact that scaled with applied current and locally obliterated imaging signal (Fig 1, C-E). The artifact created by MARC catheter activation was evident on subtracted images without obscuring the arterial anatomy, permitting catheter tracking during catheter deflection. Low level activation of the MARC catheter (10-50 mA) permitted catheter tracking without substantial deflection. Iterative updating of IA angiogram roadmaps permitted MARC catheter tracking over long distances and tortuous vessels.

Conclusions
IA MRA roadmapping is a simple, low SAR approach for tracking MARC catheters that allows for high temporal resolution. It requires minimal Gd dose, which allows for frequent roadmap updates, and does not obscure arterial anatomy during catheter deflection. The display is similar to that employed in digital subtraction X-ray angiography, which may ease adoption in the clinical setting.

References