Latex-Based Dual Contrast Hybrid Catheter for Passive MR-Guided Angiographic Interventions

R. R. Edelman[1,2], W. Li[3], A. Farrell[3], E. Dunkle[3], and I. Koktzoglou[3,4]
[1]Radiology, NorthShore University HealthSystem, Evanston, IL, United States, [2]Radiology, Northwestern University, Chicago, IL, United States, [3]NorthShore University HealthSystem, [4]Radiology, University of Chicago, Chicago, IL, United States

Introduction. Potential benefits of MR-guided endovascular interventions include elimination of x-ray exposure and improved soft tissue visualization. With active tracking techniques, microcoils affixed to the catheter are displayed with high conspicuity and frame rates. However, catheter designs are technically challenging and entail potential risks from RF heating. Passive tracking techniques typically use susceptibility-based imaging with paramagnetic markers (1). However, the susceptibility effect is spatially broad and does not allow for precise catheter localization. T1-based techniques (e.g. using a thin gadolinium coating (2)) suffer from relatively low catheter conspicuity. In order to overcome existing limitations of passive tracking techniques, we have implemented a hybrid catheter design which enables dual contrast mechanisms. An inner coating consisting of iron oxide deposits provides a susceptibility effect, whereas an outer latex coating provides high conspicuity with a T1-weighted ultra-short echo 3D radial acquisition.

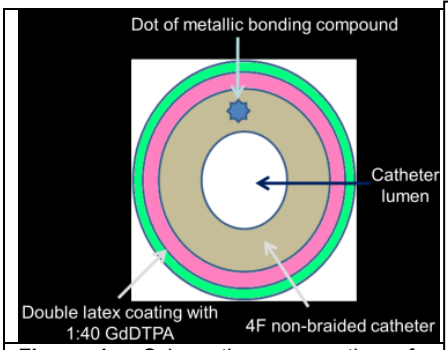

Figure 1. Schematic cross-section of a hybrid catheter, with an inner layer containing iron oxide deposits and an outer layer containing Gd-doped latex.

Subjects and Methods. The hybrid catheter design is illustrated in **Figure 1**. The core is a standard 4F angiographic catheter (AngioOptic OmniFlush 65cm .035in, AngioDynamics, Latham, NY). Dots of iron oxide-containing compound ((Loctite Weld Bonding Compound, Henkel Corporation, Avon, OH) were placed at intervals along the surface of the catheter. Next, a coagulant was applied to the catheter followed by liquid latex (Killian Latex Inc., Akron, OH) doped with dilutions of GdDTPA ranging from 1:5 to 1:40. After the latex had dried, a second latex coat was applied. Imaging was performed using Yorkshire pigs with approval from the Institutional Animal Use Committee. A 9F introducer was placed either into the femoral artery or vein (for imaging of the aorta or inferior vena cava respectively). The hybrid catheter was passed through the introducer under real-time guidance using an in-room monitor. For real-time imaging, a 2D spoiled gradient-echo pulse sequences was applied (TR/TE/flip = 11ms/6.25ms/15deg, BW 200 Hz/pixel, ipat2, slice thickness 10mm, 40% or 100% phase resolution, no flow compensation or three-directional flow compensation). For high spatial resolution imaging, either a spoiled 3D gradient-echo pulse sequence (TR/TE/flip angle = 2.3ms/0.86ms/25deg) or a 3D radial pulse sequence (dual TE = 0.05ms/3.53ms, TR 5.39ms, flip 30deg, BW 635, isotropic 1.7mm, 192 slices, scan time 2min 42sec) was used. For dual echo UTE, catheter conspicuity was compared for subtraction of the two echoes vs. single echo for 6mm and 20mm maximum intensity projections.

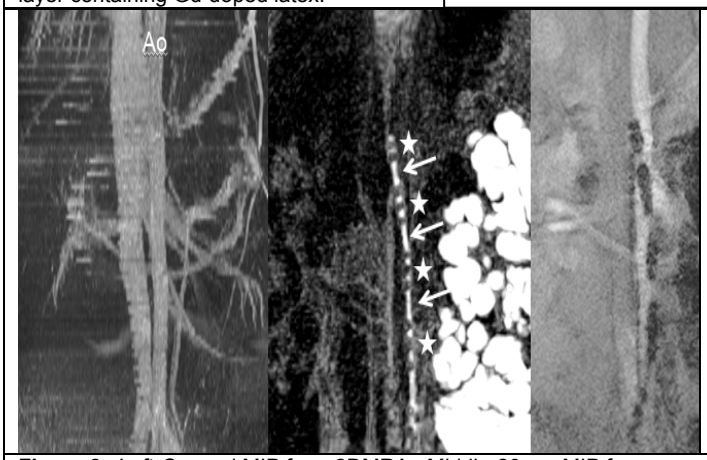

Figure 2. Left-Coronal MIP from 2DMRA. Middle-20mm MIP from dual TE 3D radial acquisition using subtraction of long from short echo. Latex appears bright (arrows) whereas the iron oxide markers appear dark (stars). Right-10mm-thick 2D GRE acquisition shows the signal void from the markers contrasting with vessel and background signal.

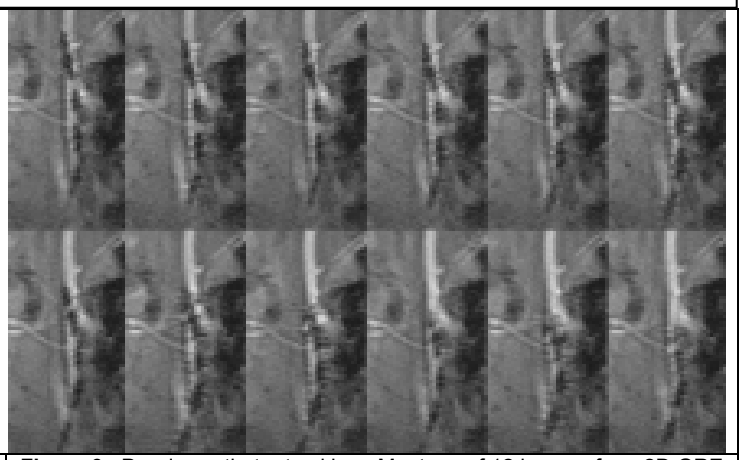

Figure 3. Passive catheter tracking. Montage of 12 images from 2D GRE acquisition using 10mm slice thickness, flow compensation, and 40% phase resolution to shorten scan time (2Hz frame rate). The length of the catheter can be visualized in all frames as the catheter is pulled back.

Results. Optimal signal enhancement was obtained by doping the latex with a 1:40 dilution of GdDTPA, which provided a 57% increase over undoped latex for UTE with a flip angle of 30 degrees. As expected based on prior reports (3), the signal intensity of the latex was found to increase down to the shortest TE that could be obtained. Consequently, 3D radial UTE (min TE = 0.05ms) was dramatically superior to 3D gradient-echo (min TE = 0.86ms). The use of a dual echo radial acquisition with image subtraction improved catheter visualization on thick MIPs (up to 20mm) by suppressing background signal and reducing partial volume averaging **(Figure 2)**. For imaging of the iron oxide deposits, selection of sequence parameters was less critical. For instance, the catheter could be well visualized even when phase resolution was reduced to 40% to improve the frame rate **(Figure 3).** Because of blooming of the marker-induced signal void, the catheter could be visualized even when out of plane. Flow compensation ensured consistently bright vascular signal in contrast with the signal voids from the markers; severe pulsation artifacts were observed when flow compensation was not applied.

Conclusions. A hybrid catheter design has been implemented based on a standard angiographic catheter. It uses deposits of an iron oxide-containing compound to enable thick slice dynamic imaging with a T2*-weighted acquisition having a frame rate of 2Hz. An outer coating of gadolinium-doped latex enables static imaging with high spatial resolution using a T1-weighted dual echo 3D radial acquisition. Although latex has not previously been used for passive catheter tracking, it was found to produce high catheter conspicuity on T1-weighted UTE images, which was further enhanced by doping with dilute gadolinium along with image subtraction. A dynamic T2*-weighted acquisition enables passive tracking of the entire length of the hybrid catheter as it is moved within the vessel, whereas the T1-weighted 3D radial acquisition can be used for more precise localization (e.g. when a branch vessel is being catheterized). The use of a hybrid catheter appears to represent a promising new approach for passive catheter tracking.

Acknowledgment. This work was supported by R21HL092386. **References:** 1. Peeters JM et al 2006 Phys. Med. Biol. 51 N127. **2.** Unal O et al. JMRI 2006; 23:763–769. 3. Alt S et al. Magn Reson in Med 2010; 64:271–279.