Endovascular Catheter for Magnetic Navigation under MRI Guidance: Evaluation of Heating In Vivo at 1.5T

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Purpose

Endovascular navigation under MRI guidance can be facilitated by a catheter with electrical current carrying microcoils on the tip. Not only do the microcoils create a visible artifact to allow catheter tracking, but also they create a small magnetic moment that attempts to align with the strong B_0 magnetic field of the MR scanner, thus permitting remote controlled catheter tip deflection. We determined the upper boundary of electrical currents safely usable at 1.5T in a coil-tipped microcatheter *in vivo*.

Materials and Methods

A 2.7F Tracker-18 microcatheter served as the substrate. A solenoid of 75 turns was created from 0.0015 inch copper wire on the outer surface of a 1.3 mm diameter alumina tube, with wire wound into thermal epoxy for adherence. Final layers of epoxy and heat shrink were applied over the solenoid. Two lead wires were attached to microcoil leads proximal to the catheter tip. The leads were pulled through the catheter lumen and a modified Thuoy-Borst Y-adaptor at the microcatheter hub, allowing saline to be infused through the side port.

A solenoidal coil-tipped catheter with luminal saline drip was navigated under x-ray guidance to the common carotid artery (CCA) of a pig via transfemoral percutaneous access. The pig was moved to a 1.5T clinical MR scanner and imaging was performed with a steady state free precession (SSFP) sequence (TR = 5.5 ms, TE = 1.6 ms, flip angle = 30º, 128 x 128 matrix, 5-6 mm slice thickness, SAR = 3.7 W/kg). Continuous direct current (0 mA to 600 mA) was then applied to the catheter microcoils for zero to 5 minutes at various points in the CCA. The catheter was then navigated to the contralateral CCA, the CCA was ligated or balloon-occluded proximal to the catheter tip (in order to achieve zero flow conditions in the artery) and the experiments were repeated. Postmortem histologic analyses of the CCAs were performed to assess potential thermal or mechanical damage. We conducted *in vivo* experiments on 6 swine carotid arteries in total.

Results

No damage to the catheterized porcine common carotid arteries was detected by gross examination or histologic analysis at 0 to 300 mA of current application for up to 5 minutes. Under conditions of zero arterial flow, platelet and fibrin coagulum was detected adherent to the endothelium of the ligated artery or detached in the arterial lumen in 3 of 6 samples. Under conditions of normal arterial flow, however, no histologic damage or coagulum was indentified. At 600 mA tip current, carotid wall damage and luminal thrombus was evident, thus establishing that this catheter system can deliver detrimental levels of energy to the arterial wall at levels of current higher than those that are likely necessary for tip navigation.

Conclusion

Preliminary *in vivo* testing of our magnetic catheter system demonstrated no thermal injury to vessel walls at normal and zero arterial flow at 300 mA, but damage was evident at 600 mA. These experiments will serve as the basis for further testing under different scenarios of catheter navigation.

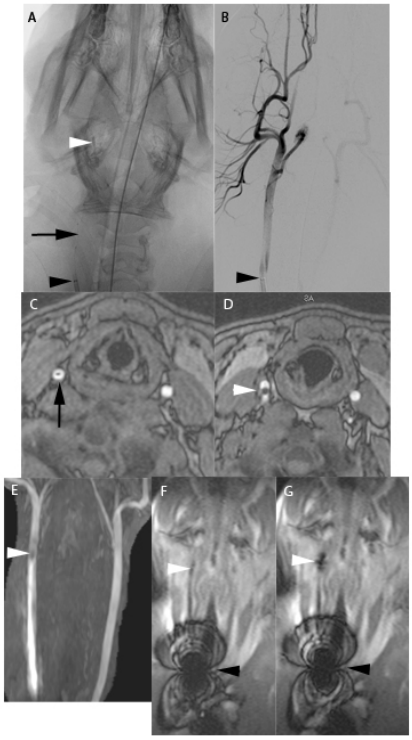

Figure 1 (Left). Unsubtracted X-ray image (A) demonstrates deflection catheter tip coils (white arrowhead), microcatheter shaft with lead wires (black arrow), and guiding catheter (black arrowhead) in the right CCA. Only the guiding catheter tip marker is readily evident on the equivalent DSA image (B). Susceptibility from the catheter shaft lead wires (black arrow) and catheter tip (white arrowheads) is seen on axial MRA (C, D), coronal MRA MIP (E), and coronal SSFP (F). With 300 mA current applied (G), the catheter tip coils are more apparent (white arrowhead). Guiding catheter tip artifact due to metallic marker band is very prominent on the SSFP sequence (F, G).

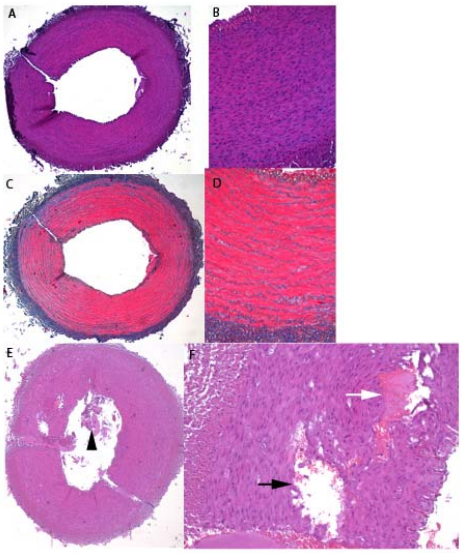

Figure 2 (Right). Porcine carotid artery wall histology after use of endovascular catheter tip coils at 300 mA tip current for 1 minute at normal flow (A-D) or 600 mA tip current for 2 minutes at zero flow (E, F). There is no evidence of vessel wall damage on hematoxylin and eosin (A, B) or Masson trichrome (C, D) at 300 mA. At 600 mA, however, luminal thrombus (E, black arrowhead), extensive medial vacuolization (F, black arrow), and medial hemorrhage (G, white arrow) all indicate thermal damage to the arterial wall.