Practical Considerations for Toroidal Transceive Interventional Device Visualization

Maryam Etezadi-Amoli[1], Pascal Stang[1], Adam Kerr[1], John Pauly[1], and Greig Scott[1]
[1]*Electrical Engineering, Stanford University, Stanford, CA, United States*

Target Audience: Interventional MRI community

Purpose: Visualization of conductive guidewires and catheters in a manner safe from RF-induced heating is an important challenge in interventional MRI. Previous work demonstrated the feasibility of using a toroidal transmit-receive (transceive) coil at 1.5T to visualize a conductive EP ablation catheter by allowing controlled low levels of RF current to flow in the device [1,2].

Here, we investigate some of the practical challenges of toroidal transceive device visualization, such as compatibility with projection imaging, use at higher field strengths and in a non-phantom setting, and the effect on image quality when the interventionist touches the catheter/guidewire. We also present heating data at both the insertion point and tip of the device.

Methods: Toroidal transceive coils were built for both 1.5T and 3T (Fig. 1). A mock EP ablation catheter (insulated wire, 130cm total length, with 5mm of exposed tip conductor) was inserted in a saline gel phantom in a 1.5T scanner. An optically-coupled toroidal RF current sensor [3] on the wire outside the phantom and a bi-directional coupler in the amplifier transmit chain were used to monitor current and power during the scans.

To test compatibility with projection imaging, low-power coronal GRE projection images (TR/TE = 50/6ms) were acquired using toroidal transceive and 11mW peak transmit power. Both straight and curved wire configurations were tested to vary the wire geometry and immersion length. To mimic conditions in an intervention, the wire was touched during the scan, and projection images and current sensor measurements were acquired to see the effect. Fluoroptic temperature measurements at the wire tip and base insertion point in the phantom were acquired at different peak RF transmit power levels to test if the low power levels needed for device visualization present a heating hazard.

To test toroidal transceive device visualization at a higher field strength and non-phantom setting, images of an EP ablation catheter inserted in the esophagus of a pig cadaver were acquired on a 3T scanner. The catheter was marked with nickel paint 5cm away from the tip so that tip visibility could be confirmed in the resulting image.

Results: The EP ablation catheter can be visualized from base to tip in projection images using just 11mW of peak transmit power (Fig 2a,b, white arrows indicate wire tip location, black gaps are plastic wire holder in phantom). Touching the wire during the scan results in a ghosting-like image artifact (Fig. 2c). Fig. 2d,e show the RF current sensor measurements for all 256 TR's of imaging. Touching the wire can cause 10-15% variation in peak RF current delivered to the wire, due to loading changes.

No heating was observed at the wire tip or base for peak transmit power levels less than 2W (Fig. 3). Power had to be increased to 8W and higher to observe any heating in the phantom. Heating at the base of the wire was less than 0.5°C for all power levels tested.

The tip of the EP ablation catheter was successfully visualized at 3T in the pig cadaver (Fig. 4b).

Discussion & Conclusion: A toroidal transceiver can be used to visualize conductive catheters that have a small area of exposed tip conductor. The method is extendible to 3T, compatible with projection imaging, and the power levels required for device visualization appear to be orders of magnitude lower than the levels that induce heating in phantom tests. Remaining challenges include safely integrating toroidal transceive device visualization with the visualization of surrounding tissues during a real interventional procedure.

References: [1] Etezadi-Amoli et al., Proc. 19th ISMRM, p1749, 2011. [2] Etezadi-Amoli et al., Proc. 20th ISMRM, p208, 2012. [3] Etezadi-Amoli et al., Proc. 21st ISMRM, p723, 2013.
Acknowledgement: We thank Andrew Holbrook and Donna Bouley for facilitating the 3T pig experiment. NIH grant support: R01EB008108, R33CA118276, P01CA159992.

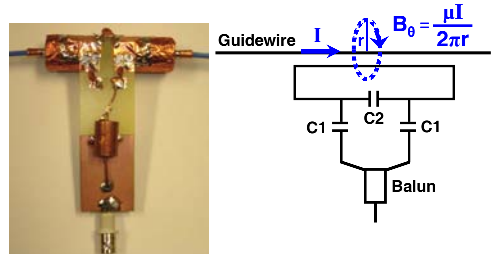

Figure 1: The toroidal transceive coil is a volume-rotated surface coil that inductively couples to any conductive structure fed through its cavity.

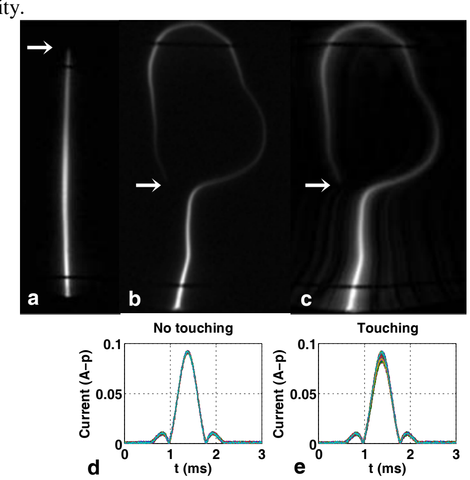

Figure 2: 1.5T coronal GRE projection image, 11mW transmit power, (a) straight wire with 38cm immersion length and (b) curved wire, 74cm immersion length. (c,d,e): Effect of touching wire during scan, 1.1W transmit, projection image (c), and current sensor measurements with (e) and without (d) touching wire.

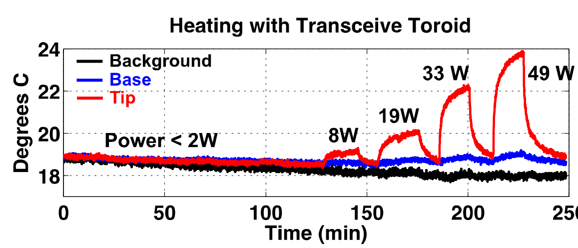

Figure 3: Fluoroptic temperature measurements at wire tip, base (entry point into phantom), and background for various peak RF transmit power levels at 64 MHz. No heating is observed for transmit power levels < 2W.

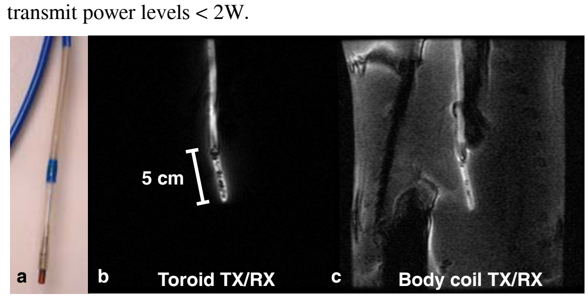

Figure 4: Pig cadaver device visualization at 3T. (a) EP ablation catheter. (b) Resulting GRE image using toroidal transceive coil. (c) Body coil T/R image for anatomical reference.