WHOLE SHAFT VISIBILITY FOR POLYMER-BASED ACTIVE iMRI CATHETERS USING HYBRID BRAIDED TUBES

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INTRODUCTION

Catheter visualization and tracking remains a challenge in interventional MRI. For safe MR guidance of vascular devices, the interventionalist must be able to see both the distal tip and shaft of the catheter relative to the vascular system and surrounding anatomy. Active visibility of the entire shaft for a guidewire is feasible because its components are comprised of a conductive metal wire and thin-walled hypotubes. Polymer-based catheters, on the other hand, provide a challenge as there is no conductive medium along its length to carry radio frequency waves. To overcome this limitation, braiding that is typically used to provide structural support to a catheter was used to receive RF signal. We have developed a clinical grade 7 Fr multi-purpose catheter constructed from tubes lined with a lattice of nitinol and copper wires, resulting in a hybrid shaft that conducts MR signal efficiently while preserving mechanical strength. We observed a bright signal along the catheter's whole shaft and no reduction in the instrument's torquability and flexibility in both in vitro phantom and in vivo animal studies.

METHODS

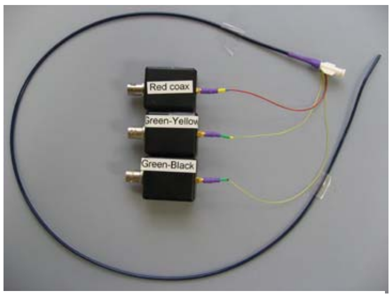

Fig 1. Active 7 Fr catheter with two loop coil channels and 1 monopole channel.

The 7 Fr catheter was constructed in a Class 10,000 cleanroom from two braided tubes, one layered over another in a monopole antenna configuration (Figure 1). A sixteen head braiding device was used to determine optimum copper wire to nitinol wire density ratio for the inner and outer braided tubes. Density ratio was adjusted to achieve the most efficient signal transmission without compromising the catheter's handling characteristics. To keep the total diameter of the catheter under 7 Fr, flat wires (0.003" width x 0.001" thickness) were used in the braiding rather than round wires. In addition, the polymer exterior of the inner braided tube was designed with eccentric 0.016" diameter grooves to hold micro coaxial transmission lines for distal tracking coils that were wound around the distal end of the catheter, one located at the tip and the other placed 3 cm down. These coils served as markers for the tip's position and also provided visual feedback of its orientation in the body. In vitro phantom and animal scanning experiments were performed using 1.5 T Siemens Espree scanner. A TrueFISP sequence was used (TR=3.31 ms, TE = 1.66 ms, flip angle = 45, slice thickness = 6 mm, matrix size= 108x192) to test visibility of tip coils and shaft profile and overall mechanical properties. Custom design software was also used to highlight each individual channel with a different color and superimposed onto the background image.

RESULTS

The braiding in the catheter permitted easier application of torque and advancement of the catheter in the animal during in vivo experiments. The catheter was flexible enough to follow vasculature without much resistance. The presence of copper wire weaved into the nitinol braiding allowed good visualization of the whole distal shaft during in vitro and in vivo real time scanning. High signal around the tip coils was also observed (Figure 2 and Figure 3). While the signal from the shaft was lower than the signal seen at the loop coils, there was still great contrast in intensity from the background.

Fig 2. Catheter in water phantom with color overlay for each channel. Red corresponds to the loop coil at the distal tip, green to the loop coil 3 cm down, and blue to the monopole antenna.

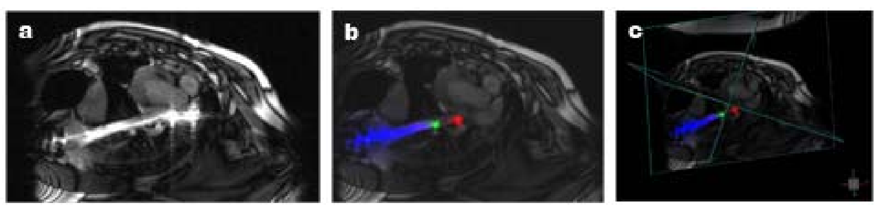

Fig 3. Real time images of catheter in porcine inferior vena cava without color overlay (a), with color overlay (b), and in 3D display (c). Color key remains the same as in Fig 2.

CONCLUSION

In addition to tip tracking, we have achieved whole shaft visualization for the polymer-based catheter using hybrid coaxial braided layers. The combination of copper and nitinol flat wires in the braided tubing produces a hybrid utilizing features of both materials. Copper provides acceptable signal transmission over the designed monopole stub while nitinol's superelasticity provides good torque transmission and flexibility for the catheter that copper alone could not have achieved. Utilizing the braided layer instead of a rigid metal structure to conduct RF yields three advantages: 1) the catheter's mechanical requirements remain undisturbed, 2) overall profile is lowered, and 3) heating of the braided layer is prevented because it is used as part of the RF transmission line and decoupled during scanner transmit mode.