

Conspicuous MRI Guidewire with an embedded temperature probe to enhance RF safety

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Target Audience: MR interventionalists and engineers.

Purpose: Interventional cardiovascular MRI is hampered by the unavailability of safe and conspicuous guidewires. One problem is RF induced heat on long, conductive wires during MRI [1]. A second problem is insufficient device conspicuity[2]. In this work, we present a 0.035" clinical grade MRI compatible conspicuous guidewire incorporating an embedded fiberoptic temperature probe to monitor RF induced heating in real-time during MRI.

Methods: The active guidewire was constructed from medical grade materials in a cleanroom, Figure 1A. A tapered 0.25 mm diameter, 128 cm long nitinol rod (NDC, Fremont, CA) serves as the inner conductor and a larger nitinol hypotube (0.81 mm OD, 0.66 mm ID) having a custom spiral-laser-cut pattern at the distal end serves as the outer conductor of a loopless antenna. The loopless antenna design was modified by attaching a solenoid coil to the tip of the guidewire to enhance tip visibility, Figure 1B. Different solenoid lengths (10 to 50 mm) and diameters (0.61 to 0.81 mm) were tested empirically to optimize the tip signal to shaft signal ratio and heating on the guidewire. The guidewire incorporated an embedded polyimide port for an internal (0.15 mm diameter) fiberoptic temperature probe, Figure 1C. The polyimide port enabled the temperature probe to be withdrawn along the entire shaft to obtain a heating profile of the guidewire. Temperature increase was calculated during a one minute scan in an ASTM 2182 phantom. Heating tests were performed in a 1.5 T (Espree, Siemens, Erlangen, Germany) MRI scanner with the following scan parameters: bSSFP; TR/TE, 3.23/1.62 ms; flip angle, 45°; slice thickness, 6 mm; field of view, 340x340 mm; matrix 192x144. Finally, overall performance of the guidewire was tested in animal experiments

Results: Electrical attachment of a solenoid coil to the tip of the inner conductor rod not only enhanced the signal at the distal end of the guidewire but also created a distinct tip signal, Figure 2 (white arrow). Table 1 shows tip signal relative to shaft signal and maximum heating normalized to the worst-case prototype. A solenoid configuration 2.5 cm in length and 0.71 mm in diameter has the maximum tip to shaft signal and moderate heating compared to all configurations. Figure 3 shows the heating profile of the guidewire during a one minute scan, obtained by continuous temperature probe pullback during MRI. Maximum in vitro temperature increase was 24.7 °C at 2.5 cm on the guidewire (hottest spot), which corresponds

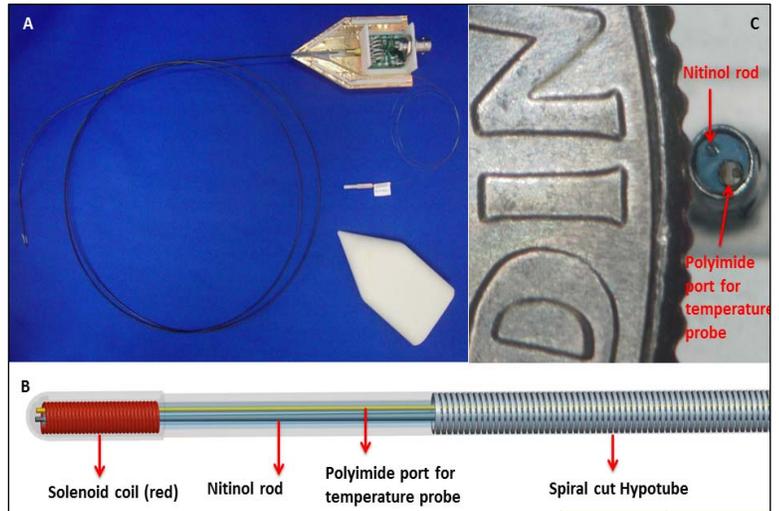


Figure 1: A-Guidewire components were insulated with a final layer of biocompatible thermoplastic polymer (Pebax, black). B-Detailed drawing of the distal 25cm of the guidewire. C- Cross-section of the guidewire at 60x magnification

Table 1 Tip/shaft signal ratio and normalized maximum heating on guidewire prototypes with different solenoid configurations

Solenoid Length (cm)	Solenoid Dia.			
	0.61 mm	0.71 mm	0.81 mm	
1	Tip/shaft signal ratio	0.27	0.33	0.55
	Maximum heating	0.27	0.26	1
2.5	Tip/shaft signal ratio	0.53	0.74	0.69
	Maximum heating	0.55	0.59	0.25
5	Tip/shaft signal ratio	0.38	0.4	0.65
	Maximum heating	0.15	0.16	0.22

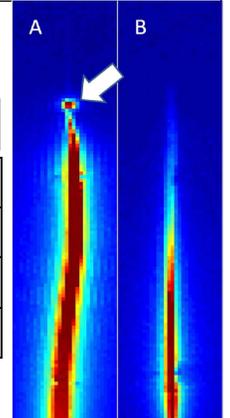


Figure 2: Images acquired by the modified loopless design (A) and the loopless design (B)

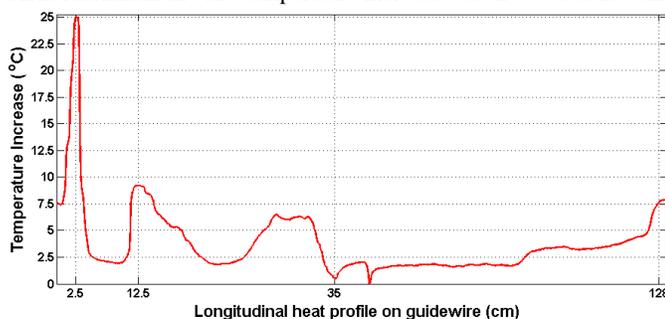


Figure 3: The longitudinal heating profile of the guidewire during a one minute scan was obtained by continuous probe pullback from the distal tip (0 cm) to proximal end (128 cm). There are significant temperature changes at transition points such as the proximal end of the solenoid coil (2.5 cm), the inner rod/outer hypotube junction (12.5 cm), and the phantom exit (35 cm).

to the proximal end of the solenoid coil. The guidewire was advanced from the iliac artery to the aortic arch in Yorkshire swine (51 kg) (approved by NIH animal care committee), Figure 4. Uniform shaft signal and distinct tip signal enhanced the safety of the procedure. During the experiment the temperature probe was positioned at the hottest spot (2.5

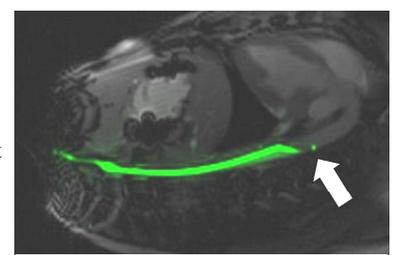


Figure 4: In vivo image of guidewire in aorta of swine. Guidewire has a conspicuous signal at the tip (white arrow).

cm) on the guidewire and no significant heat increase observed at a 45° flip angle. A 4.2°C temperature increase was observed when the flip angle was increased to 90°.

Discussion: Electrical attachment of a solenoid coil to the distal tip of a loopless antenna created a distinct signal at the tip. Tip signal and maximum heating on the guidewire were optimized with solenoid coil 2.5 cm in length and 0.71 mm in diameter. An embedded fiberoptic temperature probe enabled real-time temperature monitoring and allowed detection of unwanted RF induced heat on the guidewire. The difference between temperature increase in vitro (24.7 °C) and in vivo (4.2 °C) suggests that the ASTM phantom is not a realistic model to evaluate the RF safety of MRI devices.

Conclusion: We designed an active guidewire with distinct tip signal, uniform shaft signal and an embedded fiberoptic temperature probe at the "hottest spot" location to monitor RF induced heating in real time without affecting the device functionality adversely.

References: 1- Konings, M. K., L. W. Bartels, et al. JMIR2000 2- Ocali, O. and E. Atalar, MRM, 1997