Journal of Cardiovascular Magnetic Resonance

Meeting abstract

2107 "Bright when tight": a wireless resonant staple for interventional MRI

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from 11th Annual SCMR Scientific Sessions
Los Angeles, CA, USA. 1–3 February 2008

Published: 22 October 2008

Journal of Cardiovascular Magnetic Resonance 2008, **10**(Suppl 1):A376 doi:10.1186/1532-429X-10-S1-A376

This abstract is available from: http://jcmr-online.com/content/10/S1/A376

Introduction

Catheter-delivered fixation devices may be useful for MRI-guided endovascular surgery to fasten devices and tissues.

Successful deployment and attachment must be clearly evident. Passively-visualized staples may not provide the high contrast against the surrounding tissue and blood necessary to indicate geometry and fixation state. We have designed an active wireless device that employs a resonant circuit tuned to resonate only when the staple is successfully deployed. In the deployed state, the receiver coil inductively couples to surface and body coils for visualization.

Methods

We assembled the body of the staple using polyetheretherketone (PEEK) tubes. Thin nitinol wires heat-treated to a prescribed curve were secured within the smaller-sized tube. The outer tube was placed over the nitinol hooks to serve as a sheath until they were pushed out to pierce tissue (see Figure 1). A small micro coil was placed on the sheath and tuned with a non-magnetic ceramic chip capacitor to 63.87 MHz. A mechanical test was conducted to determine whether these hooks could release without deformation and hold onto a piece of tissue. Water phantom images were also acquired with a Siemens Sonata 1.5 T scanner. Two channels of the spine coil and two channels of the surface coil were used to transmit RF signal, and any signal around the micro coil was amplified during receive mode via inductive coupling to these coils. Images of the staple in the sheathed and deployed state were obtained using a single shot steady state free precession (TE/TR 1.96/3.9 ms, flip angle 60°, matrix 256 × 128, voxel size 1.3 × 1.3 × 5 mm^3, BW 700 Hz/pixel). The staple was placed along different orientations and

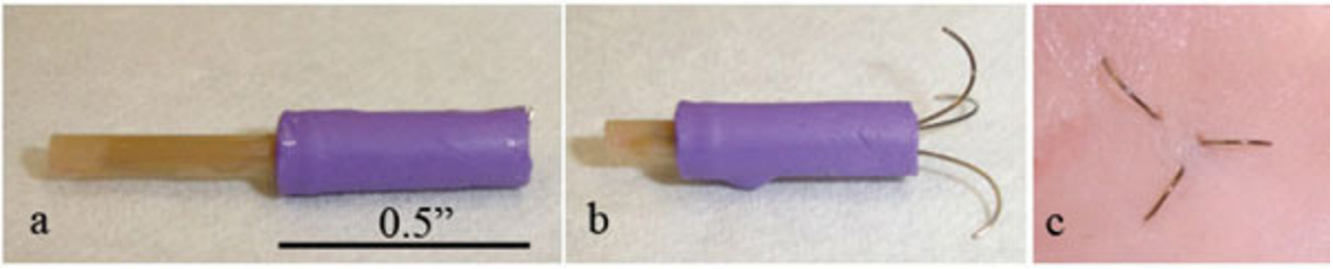

Figure 1
a) sheathed, b) deployed, c) short axis view from top of the hooks after piercing tissue.

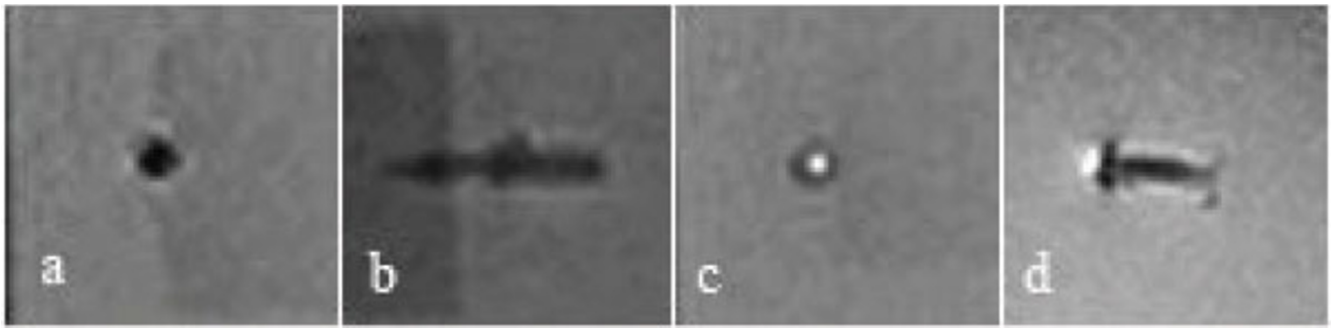

Figure 2
Short and long axis views of the staple, sheathed (a, b) and deployed (c, d). All images obtained while micro coil was oriented along the Y-axis.

SNR measurements of the device and background were taken for comparison.

Results

In the mechanical test, the hooks released without complication, regaining their curved shape as they pierced tissue. Hooks entered cleanly and secured tissue well. Scans of the staple in phantom revealed a clear state change between sheathing and deployment. No observable RF signal amplification was found within the micro coil in the staple's sheathed state. From the short axis view of the device, only a dark spot could be seen within the lumen of the outer tube, verifying that the nitinol hooks and part of the inner tube were inside the sheath. Positioning the sheathed staple along different orientations with respect to the B_o magnetic field did not result in a change from this state. When the hooks were pushed out of the sheath, however, SNR values increased up to two-fold around the location of the micro coil. The highest signal contrast was observed when the micro coil was oriented along the Y axis (see Figure 2), followed by good visualization even in the X-axis. However, such contrast could not be observed when the micro coil was oriented along the Z-axis (see Table 1).

Discussion

We have developed a prototype staple with two resonant states: low SNR when loaded for delivery and high SNR with great contrast to the background when deployed. In the delivery state, packing the nitinol fixation hooks within the vicinity of the micro coil detunes the circuit to sufficiently suppress inductive coupling. This staple has been designed to accommodate up to 0.036" guidewire for a dedicated delivery system. A safer catheter-based application of this device should be feasible after further miniaturization.

Table 1: SNR values obtained from the short axis view of the staple.

Device to Background CNR		
Micro Coil Orientation	Sheathed	Deployed
X	0.197 ± 0.002	2.146 ± 0.083
Y	0.234 ± 0.007	2.146 ± 0.083
Z	0.198 ± 0.003	0.664 ± 0.019