An Active Delivery Cable for VSD Closure under MRI-guidance

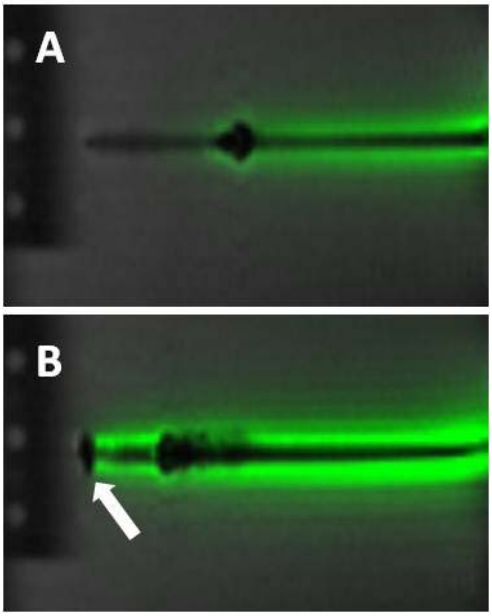
J. A. Bell[1], C. E. Saikus[1], K. Ratnayaka[1,2], I. M. Barbash[1], A. Z. Faranesh[1], M. C. Slack[1,2], R. J. Lederman[1], and O. Kocaturk[1]
[1]Translational Medicine Branch, Division of Intramural Research, National Heart, Lung, and Blood Institute, National Institutes of Health, Bethesda, MD, United States, [2]Cardiology Division, Children's National Medical Center, Washington, DC, United States

Introduction:
Congenital cardiac defects such as atrial septal defects or ventricular septal defects (VSDs) are often closed in the cardiac catheterization lab under fluoroscopy using self-expanding nitinol occlusion devices. MRI guidance of these procedures is appealing to provide soft-tissue visualization and greater anatomic context without ionizing radiation exposure. Commercial delivery systems typically contain stainless steel components which cause significant imaging artifacts under MRI (1). We have created an active MRI-compatible delivery cable incorporating a loopless antenna that enables greater visualization of the occlusion device during delivery and deployment under MRI.

Methods:
An active delivery cable incorporating a loopless antenna was constructed with a gold-plated nitinol rod as the inner conductor and nitinol hypotube as the outer conductor. The distal tip of the inner rod was welded by a Nd:YAG laser to a custom titanium screw which secures it to the occlusion devices during delivery. A thermoplastic elastomer (Pebax) was used to insulate the inner rod from the hypotube as well as to provide a final layer for the whole delivery system. The active delivery cable was tuned and matched to 50 Ω at 64 MHz with the Occluder device attached to the screw on the distal tip and with one disk deployed from the delivery sheath. This enabled the operator to observe minimal signal when neither of the disks were deployed and maximal signal when the first disk was deployed.

Animal protocols were approved by the Institutional Animal Care and Use Committee. All imaging was performed on a short, wide bore Siemens Espree 1.5T MRI scanner (Siemens Medical Solutions, Erlangen, Germany) with spine and body matrix coils as receivers in addition to the independent active device channels. Real-time balanced steady-state free precession (SSFP) imaging (TR/TE 3.23/1.67ms, ST 6mm, Flip Angle 45°, FOV 340x340mm, Matrix 192x144) using a separate real-time reconstruction and display system was performed during phantom testing and *in vivo* animal experiments. The delivery cable was used in receive-only and actively decoupled during radiofrequency transmission of the scanner. A water filled phantom was used for *in vitro* testing of the active delivery cable for signal characteristics and mechanical performance under MRI. The active delivery cable was also employed *in vivo* during real-time MRI-guided muscular VSD closure in swine using an Amplatzer Muscular VSD Occluder device (AGA Medical, Plymouth MN).

Results:
In vitro phantom testing showed the active delivery cable had minimal signal with the Occluder device attached and no disks deployed and maximal signal with the device attached with one disk deployed (Figure 1A and 1B). The pushability and torque response of the active delivery cable enabled easy delivery of the VSD device and release. During *in vivo* use, deployment and positioning of the distal disk in the left ventricle was apparent with the increased signal provided by the active delivery system (Figure 2, Arrow). Expansion of the second disk was indicated by further alteration in the signal appearance and position of the device artifact relative to the signal. Successful release of the device resulted in decreased signal from the active cable. Post-mortem examination confirmed proper device placement (Figure 3).



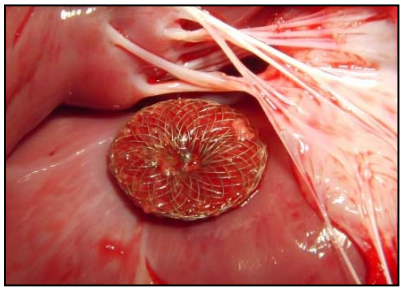
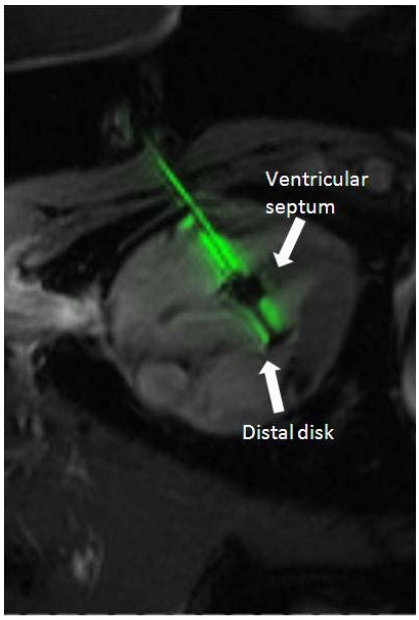


Figure 1 (left): Phantom image of the active delivery cable attached to an Occluder device with A) both disks undeployed within the delivery sheath and B) one disk deployed from delivery sheath (arrow indicates distal disk).

Figure 2 (right): Real-time MRI-guided muscular VSD closure in swine using the active delivery cable attached to an Occluder device with one disk deployed.

Figure 3 (top): Post-mortem confirmation of distal disk against left ventricular septum.



Discussion:
The active delivery cable enabled greater visualization of the Occluder device during delivery and deployment under MRI guidance. The device appearance provided by this active delivery cable combined with the superior soft-tissue visualization of MRI makes the treatment of a wide range of structural heart disease under MRI guidance feasible and promising.

References:
1. Rubin DL, Ratner AV, Young SW. Magnetic susceptibility effects and their application in the development of new ferromagnetic catheters for magnetic resonance imaging. Invest Radiol 1990; 25:1325-32.