Imaging Characteristics of an MRI-compatible Stent Delivery System

K. K. Vigen[1], J. Buzzard[2], and A. N. Raval[3]

[1]Radiology, University of Wisconsin-Madison, Madison, WI, United States, [2]Cordis Endovascular, Warren, NJ, United States, [3]Cardiovascular Medicine, University of Wisconsin-Madison, Madison, WI, United States

Introduction

Stent placement under real-time magnetic resonance imaging (rtMRI) has been demonstrated in animal models [1-3]. A major problem that limits advancement of this field is the availability of suitable MRI-compatible interventional devices. Commercially available self-expanding nitinol stents are themselves MRI-compatible; however, their stent ***delivery*** systems (SDSs) use steel or other non-MRI compatible materials. Severe local susceptibility artifacts result around the SDS preventing accurate visualization of pre-deployment stent position during rtMRI guided procedures. For this work, a commercially available SDS has been refabricated with materials resulting in significantly reduced susceptibility artifact.

Methods

Two stent delivery systems were implanted in a doped agar phantom (2% agarose in a 1mM $CuSO_4$ solution). The first was a commercially available SDS with steel components and braiding (PRECISE 6x30mm 5F, Cordis Corporation, Warren NJ). The outer and inner members consisted of PTFE, Nylon with 304 Stainless steel braid; and Nylon and 303/304 Stainless steel respectively. The second was a modified SDS (PRECISE 5x20mm, 5F) with an outer and inner members consisting of Polyamide with no braid; and Peek respectively. The wire lumen, tip, and hub identical between SDS. Metal braiding components were removed and improved MRI-compatible polymers were applied to the device to enhance kink resistance. Imaging was performed on a 1.5T MRI scanner (Signa HDx, GE Healthcare, Milwaukee WI), with both SDS versions positioned at 0°, 45°, and 90° with respect to the main magnetic field (B_0) of the MRI system. Images were acquired using the body RF coil for transmit and receive in planes longitudinal with and transverse to the devices. Images were acquired using imaging pulse sequences that are typically used during rtMRI procedures: a spoiled gradient echo (SPGR) sequence (TR/TE/FOV/Matrix = 5.0/1.2/32/256x128, 4x8mm slices); a balanced SSFP (FIESTA) sequence (TR/TE/FOV/Matrix=3.1/1.2/32/256x128); and a T1-weighted FSE sequence (TR/TE/FOV/Matrix/ETL = 7/8.8/32/ 256x128/4); all imaging sequences were repeated with swapped frequency encoding direction. The approximated FWHM (Full-Width Half Minimum) of the image signal was measured for all transverse image plane orientations at the level of the stent and more proximally across the catheter body.

Results

Both SDS systems are visibly similar (Figure 1: unmodified SDS left, modified SDS right). Figure 2 shows SPGR images of the unmodified (left) and modified (right) devices acquired in the longitudinal plane, with the devices parallel to B_0. Figure 3 shows the same acquisition, but with the devices perpendicular to B_0. In both cases, the unmodified system showed significant artifact (including a variation of the well-known needle-tip blooming artifact in Fig. 2 [4]), whereas the modified system demonstrated almost no artifact, except for some small susceptibility effects from the unexpanded nitinol stent (arrow). Figure 4 shows a balanced SSFP acquisition using a transverse section across the catheters, positioned 45° to B_0, with significant banding artifacts around the unmodified catheter, and no artifact around the modified SDS (arrow). The measured FWHM for both systems for the SPGR images are shown in Table 1; the modified system (SDS 2) has a measured FWHM across the catheter of 1.9mm, which is comparable to the nominal width (5 Fr) of the delivery system. The balanced SSFP and FSE images showed qualitatively similar FWHM results.

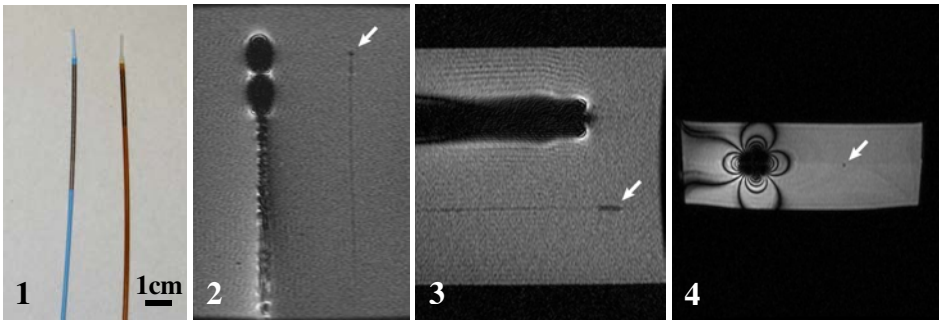

Table 1: FWHM of SDS SPGR Images.

	Site of Measure	SDS 1	SDS 2
0° (∥) to B_0	Stent	26.9mm	2.5mm
	Cath.	8.1mm	1.9mm
45° to B_0	Stent	1.9mm	3.8mm
	Cath.	46.9mm	1.9mm
90° (⊥) B_0	Stent	1.9mm	5.0mm
	Cath.	51.9mm	1.9mm

Discussion

The primary limitation of real-time MRI guided interventional procedures currently is the availability of suitable MRI compatible devices. Such devices must be devoid of ferromagnetic materials to prevent susceptibility artifacts and avoid heating. We have demonstrated that a commercially available SDS which has been modified to include no ferromagnetic materials offers significantly less artifact. The modified SDS has the potential to be ideal basic platforms upon which device MRI visualization and tracking development can occur.

References

[1] Buecker A, *et al., J Magn Reson Imaging,* **12:** 616-22 (2000). [2] Elgort DR, *et al., J Magn Reson Imaging,* **23:** 619-27 (2006). [3] Feng L, *et al., Radiology,* **254:** 558-62 (2005) [4] Liu H, *et al., J Magn Reson Imaging,* **13:** 16-22 (2001).