Active Visualization of MR-Compatible Guidewires

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Introduction:

Safety concerns exist regarding the use of conventional guidewires in an MR scanner. Recently, an MR-compatible guidewire design has been evaluated that consists of a non-resonant length of nitinol (100mm) attached to a long non-conducting segment made of a glass-fiber reinforced plastic [1, 2]. The guidewire is doped with iron powder to enable passive visualization of the device. As with other passive visualization techniques, the device cannot be located if it does not lie within the scan plane and visualization based on negative contrast can be difficult in regions containing significant structure.

The purpose of this study is to investigate a method for actively visualizing the non-resonant length of nitinol at the tip of MR-compatible guidewires by magnetically coupling the wire to a small toroidal pick-up coil located in the walls of the guide catheter, a device that is typically present to provide mechanical support for the wire (Fig 1). During the reception of MR signal, a current is induced on the short conducting segment and this appears as a voltage across the leads of the pick-up coil. A prototype device has been constructed and the technique is demonstrated in phantoms.

Our target application is MR-guided revascularization of occlusive arterial disease. In this application we are interested in visualizing the wire in cross-sectional planes to ensure that the wire is within the occluded lumen before a revascularization device is advanced.

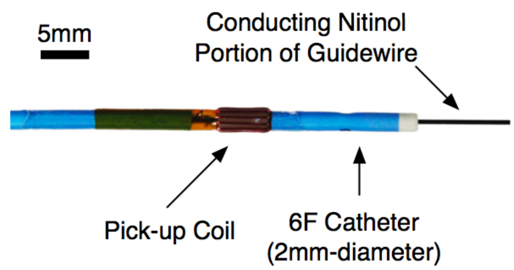

Fig 1. To perform active visualization of MR-compatible catheters, a small rectangular-shaped toroidal pick-up coil embedded in the wall of a guide catheter is used to detect currents induced on the conducting portion of guidewire. A photograph of the prototype catheter is shown.

Materials and Methods:

A small rectangular-shaped toroidal pick-up coil (15 turns, each with width=.5mm, length=5mm) was constructed over a small annular ring of PEEK (Polyetheretherketone) using 36 AWG magnet wire and embedded in the wall of a typical 6F diagnostic catheter (Cordis) (Fig 1). The pick-up coil was connected to a matching network that was located at the proximal end of the catheter via a length of .3mm-diameter coaxial cable. The maximum outside diameter of the device (at the pick-up coil) was 2.3mm. The device was constructed so that an MR-compatible guidewire could pass through the entire length of the catheter lumen and through the centre of the pick-up coil. The 5mm rigid section did not affect the overall flexibility of the catheter significantly. A 100mm segment of nitinol wire (extracted from the tip of a 0.018-inch Glidewire, Terumo) was put in the distal portion of the catheter lumen and placed in a 0.4% saline phantom. Imaging was performed on a 1.5T GE Excite scanner (GE Medical Systems, USA). Cross-sectional images through the axis of guidewire in front of the guide catheter were acquired (SPGR, TR=50ms, TE=6ms, FA=30, FOV=12cm, 256x256).

Results and Discussion:

Images acquired in cross-sectional planes through the axis of the nitinol wire are shown in Fig 2. Significant MR signal in the region immediately surrounding the wire can be seen thereby making the guidewire visible. It can also be noted that the signal in the region around the wire decreases as the imaging plane approaches the tip of the wire. This is due to the current distribution along the wire which approaches zero at the wire ends and is maximum at the centre of the wire. Although the context of this work is limited to visualization in cross-sectional planes in front of the guidewire, visualization could also be done in longitudinal planes to depict the length of the conducting portion of the guidewire.

There are several advantages associated with actively visualizing MR-compatible guidewires. The use of an MR-compatible wire may be considered to be safe for use in an MR scanner because the conducting section is limited to a non-resonant length, and as such, resonant current structures cannot develop. As with other active techniques, a safety concern still exists regarding the transmission lines used to relay the MR signal from the toroid to the scanner electronics. However, size constraints limiting safety features when the coaxial cable is connected directly to the guidewire are significantly diminished in the current approach since these cables are now inside the much larger guide catheter. This enables, for instance, the use of RF-chokes to alleviate the safety concerns [3]. As another advantage, an MR-compatible guidewire is much simpler than active guidewires based on loopless antenna designs [4] as the latter contain significant internal structure. It is therefore much easier to construct a thin guidewire with the desirable mechanical properties under the proposed approach.

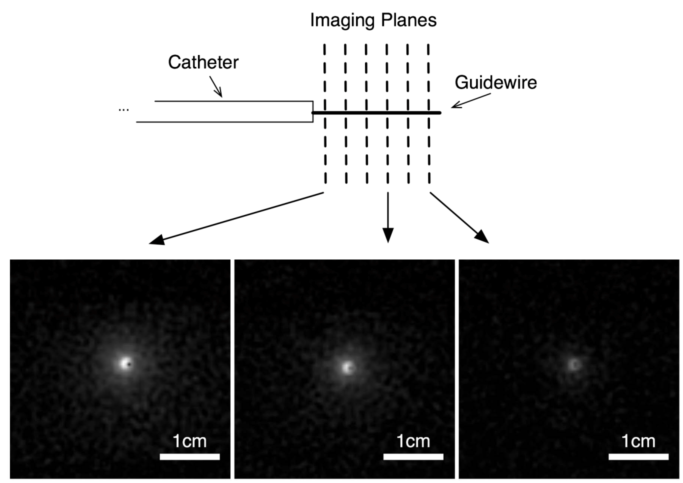

Fig. 2. Cross-sectional images of the guidewire in front of the catheter acquired with the toroidal coil. A region of high signal intensity exist in the area immediately surrounding the guidewire thereby making it visible.

Currently, the matching network is placed at the proximal end of the catheter and is separated by a length of micro-coaxial cable. Due to its small size, this transmission line has an approximate resistance of 5 ohms and is the dominant source of noise. Although this technique provides sufficient SNR for visualization, one could consider using techniques to locally tune the pick-up coil to improve the SNR so that the guidewire can be used for imaging. This approach, combined with signal void localization to identify the location of the wire with respect to the vessel wall may help the operator avoid wire extravasation when crossing occlusive lesions.

References: [1] Krueger S et al. ISMRM 2007; 291 [2] Kraemer NA et al. ISMRM 2008, 905 [3] Ladd M E and Quick H H. MRM 2000; 43:615 [4] Ocali O and Atalar E. MRM 1997; 37:112