DEVELOPMENT OF AN 0.014-IN MAGNETIC RESONANCE IMAGING-GUIDEWIRE

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Introduction

The MR imaging-guidewire (MRIG) is a co-axial cable with extension of its inner conductor [1]. The MRIG has two functions: imaging and guiding [2]. The current generations of MRIGs are made of nitinol at 0.032 inch (0.81mm) in diameter, which has been successfully applied in the middle- and large-sized peripheral arteries [2, 3]. The final goal in the development of this technique is to diagnose and treat atherosclerosis in small-sized arteries, such as the coronary arteries, which requires a thinner MRIG, ideally 0.014 inch (0.35 mm) in diameter as a standard size for both imaging and guiding. However, there are several challenges in building such a thin MRIG because of the limitations on either MR signal conductivity or the mechanical properties of the MRIG. Nitinol or similar alloys offer excellent flexibility and maneuverability of the MRIG, which address the needs of complicated endovascular interventional procedures. However, the electrical resistance of nitinol-based 0.014-in MRIG is very high, which results in high electrical attenuation, decreases the efficiency of receiving MR signal, and thus reduces signal-to-noise ratio (SNR). In this study, we attempted to develop a new 0.014-inch MRIG by plating or cladding high electrical conductive materials on the inner and outer conductors of an MR compatible coaxial cable, which was specifically designed to maintain both electrical conductivity and mechanical properties for generating high SNR MR images and guiding endovascular interventions under MR imaging.

Materials and Methods

We first calculated the electrical attenuation and character impedance with different outer diameters of the inner conductor (ODIC) and inner diameters of the outer conductor (IDOC) of 0.014-inch coaxial cables. We chose one coaxial cable with configuration at IDOC/ODIC of 228um/101um, which offered designed 1.49dB/m electrical attenuation and 26.5Ω character impedance. To build the outer conductor, we first manufactured a silver tube, 12.7-um in thickness, and then clad an MP35N alloy tube over the silver tube. MP35N is a nonmagnetic, anticorrosive, and biocompatible alloy, which has an elasticity modulus and electrical conductivity similar to nitinol. The inner conductor was made by plating a 8.6-um thick gold/silver/gold layer on a 101-um nitinol wire (Nitinol Devices & Components Inc, Fremont, CA). Next, we inserted manually the gold/silver/gold-coated inner conductor into a 12.7-um thick polymer tube that functioned as a polymer–insulator layer between the inner and outer conductors. Then, we inserted the polymer-insulated inner conductor into the silver-clad, MP35N-based outer conductor tube described above. Figure A shows the scheme of the newly-designed 0.014-in MRIG in comparison with the previously-designed 0.032-in MRIG. To compare the imaging qualities and SNRs between the 0.014-in and 0.032-in MRIGs, we built the two wires at the same length, 63 cm (Figure B).

In order to compare performance of the 0.014-in and 0.032-in MRIGs, we performed MR imaging using two MRIGs in a phantom using the identical MR imaging pulse sequence (proton weighted imaging with FSE sequence of 1400/15-ms TR/TE, 64-kHz bandwidth, 32 ETL, 1 NEX, 6-cm FOV, 3-mm thickness, and 256x256 matrix). To validate the new 0.014-in MRIG in vivo, we used two New Zealand white rabbits, approximately 4.5 kg in weight, with aortas approximately 4-mm in diameter. Through a surgical cut down, we first positioned a 4F introducer into the carotid artery, and then placed the 0.014-in MRIG into the abdominal aorta through the introducer. Along with the MRIG, we positioned a 3.2F balloon catheter, with a balloon portion of 4 mm in diameter and 2 cm in length (Boston Scientific, Boston, MA), into the abdominal aorta of the rabbits. In vivo MR imaging was performed in a 1.5 Tesla MR scanner (GE Medical System, Milwaukee, WI). We acquired axial and sagittal images of the balloon-inflated target vessel wall using: (a) proton-weighted imaging with the same parameter as used in the in vitro study; and (b) T1-weighted imaging and T2-weighted imaging with an FSE sequence. Subsequently, we replaced the 0.014-in MRIG with the 0.032-in MRIG within the same experimental setup, and performed MR scanning of it with the same imaging parameters as used for the 0.014-in MRIG.

Results

The SNR contour of both 0.014-in and 0.032-in MRIGs was closed each other as shown in figure C. In the in vivo studies, we were able to use the new 0.014-in MRIG to guide the positioning of the balloon catheter into the rabbit aorta, and to monitor the inflation/deflation of the balloon under MR imaging. On the high-resolution MR images, we could visualize the balloon-inflated target aortic wall at a resolution of 157 µm with both the 0.014-in MRIG and 0.032-in MRIG (Figures D&E). The MR imaging quality obtained with the 0.014-in MRIG was close to that of the 0.032-in MRIG.

Conclusion

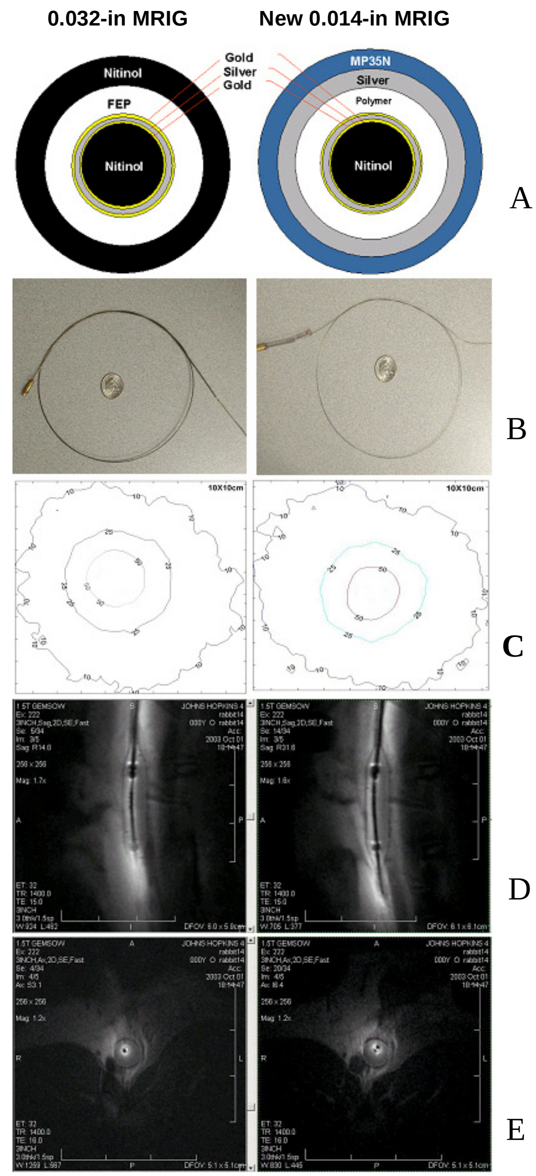
We demonstrated a newly-designed, nitinol/MP35N-based, silver/gold-coated, 0.014-in MR imaging-guidewire, which offers the necessary electrical conductivity for high resolution MR imaging of the vessel walls and the mechanical properties required to guide endovascular interventional procedures under MR imaging. This study has established the groundwork for further application of a standard-sized 0.014-inch MRIG in the management of cardiovascular atherosclerotic diseases in small-sized vessels, such as the coronary arteries, using intravascular MR imaging-based interventional therapies.

Acknowledgments

The authors thank Robert Susil, MD, PhD for his scientific discussions, and Ms. Mary McAllister for her editorial assistance. This work was supported by an NIH R01 HL66187 grant.

References

1 Ocali, O, et al., MRM 1997; 37,112-118.
2 Yang X, et al., Int J Cardiovasc Intervent 1999; 2(2),85-96.
3 Hofmann LV, et al, JVIR 2003;14,1317 -1327.



Figures. Comparison between the previously-designed 0.032-in MRIG (Right column), and the newly-designed 0.014-in MRIG (Left columna). A: The scheme of the two MRIGs. B: Photographies of the two MRIGs. C: The SNR maps of two MRIGs; D&E: The segittal and axial proton-weighed images of the balloon-inflated target vessel walls with the 0.032-in MRIG and 0.014 MRIG, respectively.