In Vivo Active Visualization of an Ablation Guidewire for the Revascularization of Occlusive Arterial Disease

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Target Audience: Interventional MRI researchers who are investigating and developing methods for device visualization and guidance.

Introduction

The percutaneous revascularization of occlusive arterial disease in coronary and peripheral arteries represents a major clinical challenge. Procedural success is currently limited by the inadequate soft-tissue contrast of x-ray fluoroscopy and its inability to visualize the position of a revascularization device with respect to the occlusive lesion and the vessel wall.

Studies investigating the use of MRI for lesion revascularization have focused on the development of specialized active catheters and guidewires that incorporate radio-frequency (RF) coils to enable device visualization.[1] There are many engineering challenges associated with this approach and the additional complexity of such devices will typically result in an associated loss in device performance.

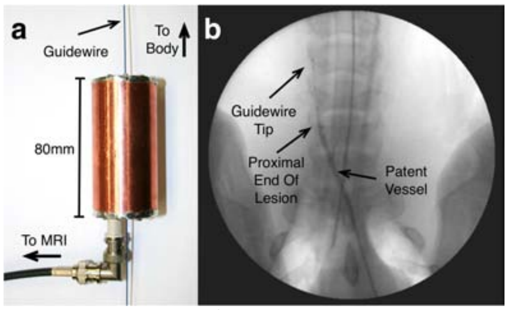

Fig 1. a) Photograph of the cylindrical coupling device used for guidewire visualization. The device magnetically couples to guidewires that are passed through it. **b)** X-ray fluoroscopy image of the guidewire inserted into the occlusive lesion of the animal model.

The purpose of this study is to investigate the ability to visualize a commercially available RF-ablation guidewire (PowerWire, Baylis Medical) that has been designed specifically for the revascularization of occlusive arterial disease without making any physical changes or modifications to the device itself. An active visualization approach is used that utilizes an external magnetic coupling device and the ability to identify the position of the guidewire inside an animal model of occlusive vascular disease is assessed.

Methods

To enable active visualization, a cylindrical copper-coated Teflon device (80mm in length and 38mm in diameter) with a hollow core (10mm in diameter) was constructed (Fig 1a). The device magnetically couples to guidewires that are passed through its core enabling MR signal to be received by the guidewire without the need for any physical connections.[2] An animal model of occlusive arterial disease was used to assess the ability to visualize the guidewire in vivo. The model was created in the right carotid artery of pigs by surgically tying off the vessel using a non-absorbable suture and maturing the lesion for approximately 3 weeks. In four pigs, the guidewire was advanced from the femoral artery under x-ray fluoroscopy into the occlusive lesion to the suture location where it could not be advanced further (Fig 1b). Once seated in the lesion, the animals were moved to a 1.5T MR scanner (GE Healthcare) and the coupling device was placed at the location of guidewire entry. Imaging of the lesions was performed in vascular / device cross-sectional (SPGR, FOV=16cm, 320x320, slice=5mm, NEX=4) and longitudinal planes (SPGR, FOV=16cm, 320x320, slice=3mm, NEX=4) using a surface coil located on the neck of the animal above the lesion. The length of the guidewire was visualized by acquiring a projection image (SPGR, FOV=24cm, 128x128, NEX=1) in the longitudinal plane with the coupling device and utilizing a 0.5 cycle/mm gradient in the through-plane direction to compensate for phase variation around the device.[3] Signal from the coupling device acquired during the cross-sectional acquisitions was reconstructed independently from that of the surface coil to depict the position of the guidewire within the vessel near the guidewire tip.

Results

The coupling device rendered the guidewire visible with signal characteristics similar to that of a loopless antenna device. The length of the guidewire could be depicted in the longitudinal plane to yield information about guidewire tortuosity and guidewire position with respect to occlusion's proximal and distal ends (Fig 2a-b). Signal reconstructions in cross-sectional planes consisted of localized signal close to the wire that could be used to infer the wire's position (Fig 2c-d). In all four in vivo experiments, it was found that adequate signal could be seen from the guidewire in the first slice proximal to the suture location and the guidewire tip could thereby be localized in the through-plane direction to within one slice thickness (5mm).

Discussion and Conclusions

The RF-ablation guidewire could be visualized using an active technique with no device modifications. The use of pre-existing intravascular devices enables one to minimize device development efforts and to pursue guidance studies with no compromise to device properties. In addition, pre-existing regulatory clearances may minimize the hurdles encountered on the path towards first-in-man studies. It should be noted that as with other active techniques, the guidewire is susceptible to the formation of currents during excitation that can give rise to tissue heating; however, as noted in [2], the coupling device will provide a certain degree of current suppression by virtue that it is also a resonant floating current trap. Future work will focus on transitioning towards full MR-guided crossing studies of more complex models of occlusive disease.

References: **[1]** Raval A., et al. Real-Time Magnetic Resonance Imaging–Guided Endovascular Recanalization of Chronic Total Arterial Occlusion in a Swine Model. Circ. 2006;113:1101-1107; **[2]** Hillenbrand C., et al. The bazooka coil: A novel dual-purpose device for active visualization and reduction of cable currents in electrically conductive endovascular instruments. 13th ISMRM. 2005;197; **[3]** Overall W., et al. Phase Refocusing for Improved Visualization of Interventional Guidewires. 15th ISMRM. 2007;1117.

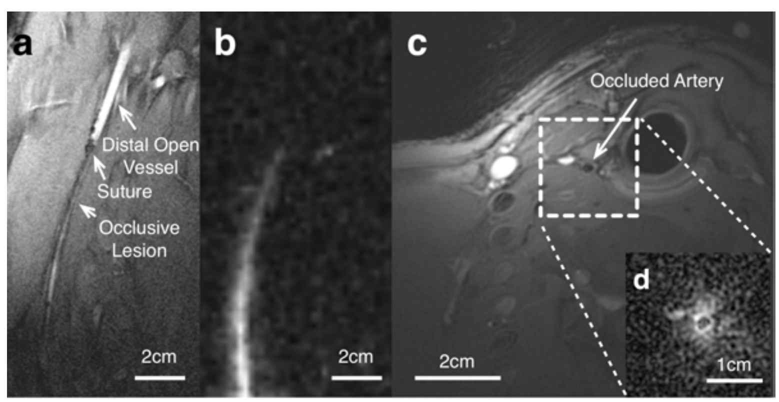

Fig 2. a) Anatomical longitudinal image of occluded carotid artery acquired with a surface coil. **b)** Image acquired from coupling device in same orientation as (a) depicting the length of the RF-ablation guidewire. **c)** Cross-sectional image of the occluded vessel acquired with a surface coil. **d)** Magnified cross-sectional image reconstructed with signal from the coupling device. The position of the image is approximately 5mm from the guidewire tip.