Spiral imaging for visualization of commercial nitinol guidewires with reduced heating

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TARGET AUDIENCE

This work is of interest to researchers and clinicians in the field of MRI-guided interventions.

PURPOSE

MRI-guidance of cardiovascular catheterization procedures offers reduced ionizing radiation exposure and improved tissue visualization. However, the clinical translation of MRI-guided catheterizations has been limited by the unavailability of MRI safe and visible interventional devices. Rigid metallic guidewires are especially challenging because they are essential for almost all catheterization procedures, yet are particularly prone to heating under MRI [1]. Here we use spiral gradient echo imaging to prevent RF-induced heating from exceeding allowed limits [2], combined with positive contrast to improve visualization of a commercially available guidewire.

METHODS

Gradient echo spiral imaging (8 interleaves, TE/TR = 0.86ms/10ms, flip angle = 10°, FOV = 300mm, matrix = 128x128) was chosen because it is RF-efficient and thus minimizes heating. Imaging was performed on a 1.5T MRI scanner (Aera, Siemens, Erlangen, Germany), variable density spiral trajectories were calculated using freely available software (http://mrsrl.stanford.edu/~brian/vdspiral/) and spiral image reconstruction was performed on an external workstation running the Gadgetron (http://gadgetron.sourceforge.net) [3]. Through-slice dephasing was used to produce positive contrast from the nitinol guidewire, such that the background signal appears suppressed and the wire appears hyperintense due to the local magnetic field inhomogeneity [4]. Acquisitions of an "anatomical image" (standard gradient echo contrast) and a "device image" (positive contrast) were interleaved. Image processing (thresholding and selection of elongated structures), was performed online on the device image to isolate the guidewire signal from background signal caused by other sources of field inhomogeneity. The guidewire signal was overlaid in color on the anatomical image in real-time to assist in procedural guidance.

MRI-guided left heart catheterization was performed on a Yorkshire swine using a standard 0.035" commercial nitinol guidewire (Nitrex, Covidien, Plymouth, MN). Animal experiments were approved by the animal care and use committee according to contemporary NIH guidelines. The interleaved positive contrast spiral imaging method, with color overlay, was used to visualize the guidewire during the procedure.

Heating at the tip of an 120 cm insulated nitinol rod was measured during imaging in a ASTM 2182 acrylic gel phantom using a fiberoptic temperature probe (OpSense, Quebec, Canada) affixed to the guidewire by polyester heat shrink tubing (Advanced Polymers, Salam, NH).

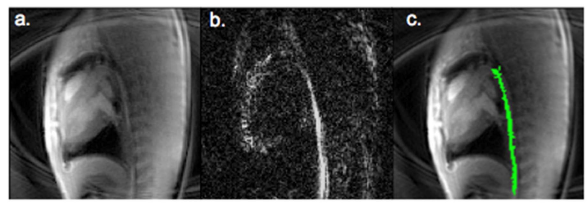

Figure 1: Anatomical image (a), positive contrast device image (b) and real-time color overlay (c) generated with gradient echo spiral imaging.

RESULTS

Pairs of anatomical and device images (Figure 1a,b) were generated at 6.25 frames/s (80ms per image). Positive contrast using through-slice dephasing provided a clear visualization of the guidewire in vivo (Figure 1b). The image processing occurred in real-time and the color overlay of the device on the anatomy was displayed to the operator throughout the left heart catheterization procedure (Figure 1c). The spiral imaging method generated only 0.47°C temperature increase at the tip of the nitinol rod during 1 minute of continuous scanning in vitro, compared to 37.2°C generated using standard Cartesian bSSFP imaging (TE/TR =1.27/2.54 ms, flip angle = 45°) (Figure 2).

DISCUSSION

Gradient echo spiral imaging uses low flip angles, long readouts and few RF pulses per image, and therefore is both RF-efficient and high frame rate, making it a good candidate for the interventional MRI setting. Here we have demonstrated that positive contrast spiral images can be generated to improve device visualization. The real-time color overlay mimics active device visualization and is therefore intuitive for operators to use. Isolation of the guidewire signal from the background was most challenging around the aortic arch due to background signal from air-tissue interfaces. The heating experiments were designed to mimic worst-case scenario, and less heating is expected in vivo due to the cooling effects of blood flow [5]. Even so, negligible guidewire heating was observed in the gel phantom when using the gradient echo spiral sequence.

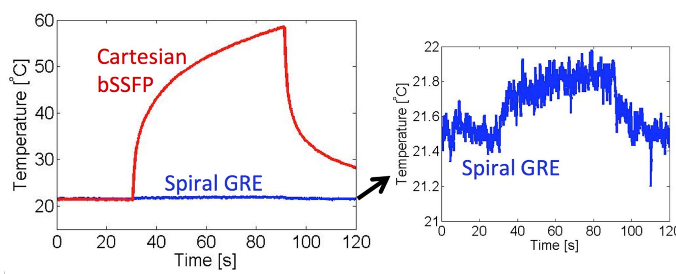

Figure 2: In vitro heating at the tip of an insulated nitinol rod during 1 minute of continuous scanning (30-90s) with Cartesian bSSFP (red) and spiral gradient echo (blue).

CONCLUSION

This technique simultaneously provides good guidewire visualization and generates negligible RF-induced heating, and thus shows promise to enable the safe use of commercially available guidewires for MRI-guided interventions.

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