Visualization and Tracking of a Conventional Guidewire with Low Flip Angle SSFP Imaging: An Initial Study

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Introduction Inductive coupling between RF transmit coils and self-resonating circuits incorporated into interventional devices combined with low-flip angle (LF) balanced SSFP (b-SSFP) imaging has been utilized in MRI for visualization of stents and catheters (1). In principle, such a coupling can also result if a conventional (i.e. radio-opaque) passive guidewire is able to carry a current in the presence of RF excitations and resonate with the B_1 field (2). The purpose of this study is to investigate whether conventional passive guidewires may be visualized and tracked with positive contrast. The presence of LF RF excitations under on-resonant conditions leads to low b-SSFP signals. Hence, the appearance of signal enhancements surrounding conventional guidewires under LF excitations: (a) permits the visualization and potential tracking of the guidewire with positive contrast; and (b) provides evidence for the possibility that even LF excitations can elicit appreciable amount of current in a conventional passive guidewire that locally amplifies b-SSFP signals. To test our hypothesis, *ex-vivo* and *in-vivo* experiments were performed using a radio-opaque coronary guidewire and LF b-SSFP imaging.

Materials and Methods All MRI experiments were performed using a 1.5 T scanner (Sonata, Siemens AG Healthcare Sector, Erlangen, Germany). *Ex-vivo* experiments were performed using a four-channel head coil, while animal experiments were performed using spine array and 6-element body array coils. Ex vivo Protocol: In order to investigate the b-SSFP signal dependence surrounding the guidewire on flip angle, a 0.018" diameter coronary guidewire (Terumo Medical Co., Japan) was placed in a blood bath and imaged at different flip angles (α =2°, 5°, 10°, 20°, 40°, and 60°) with the following imaging parameters: repetition/echo time (T_R/T_E)=4.3/2.15 ms, field-of-view (FOV)=300x300 mm^2, matrix =320x320, slice thickness = 2.5 mm, and receiver bandwidth (BW)=1115 Hz/pixel. Subsequently, the same guidewire was transferred into an aortic phantom (Elastrat; Switzerland) filled with blood. The guidewire was advanced to the aortic root under real-time LF b-SSFP MRI. Imaging parameters for the real-time protocol were: oblique-sagittal slice orientation yielding a 'candy cane' view of the aortic aorta, T_R/T_E=2.8/1.4 ms, α=20°, FOV=22.5×30 cm^2, matrix=144×192, slice thickness = 15 mm, receiver bandwidth (BW) = 1530 Hz/pixel, and frame rate = 2.5 Hz. Animal Protocol: Domestic swine (n=2, 30 kg) were sedated, intubated, and their common femoral artery was accessed using a 5-F micropuncture set and exchanged for an 8-F groin vascular sheath. A 0.018" diameter guidewire was introduced into the vascular sheath and advanced into the abdominal aorta under X-ray guidance. The animal was transferred into the MR suite and the guidewire was advanced through the aorta and into the left ventricle under real-time MRI guidance with the LF b-SSFP imaging. Imaging parameters for the acquisition were: oblique-sagittal slice orientation, T_R/T_E = 2.7/1.4 ms, α = 20°, FOV = 25×25 cm^2, matrix = 192×192, half partial Fourier, slice thickness = 15 mm, BW = 1530 Hz/pixel, and frame rate = 3.6 Hz. Data Analysis: Respective contrast-to-noise ratios (CNR), computed as signal differences between signal-enhanced regions and the background, normalized by the standard deviation of noise, were computed at the tip, medial, and distal segments of the guidewire in *ex-vivo* blood bath, aortic phantom and *in vivo*. CNR values from aortic phantom and swine were measured from images obtained at different time points and results were reported as mean ± SE.

Results Flip-angle dependent local signal amplification surrounding the guidewire was clearly evident (Fig **A** and **B**). At the optimal flip angle of 20° (Fig **B**), it was possible to visualize and track the guidewire within the aortic phantom (Fig **C**) and in swine (Fig **D**). CNR values from *ex-vivo* aortic phantom studies were: 11 ± 0.8 (tip), 39 ± 2.3 (medial), and 68 ± 3.2 (distal). CNR values from *in-vivo* studies were: 10 ± 1.3 (tip), 36 ± 0.5 (medial), and 53 ± 4.8 (distal).

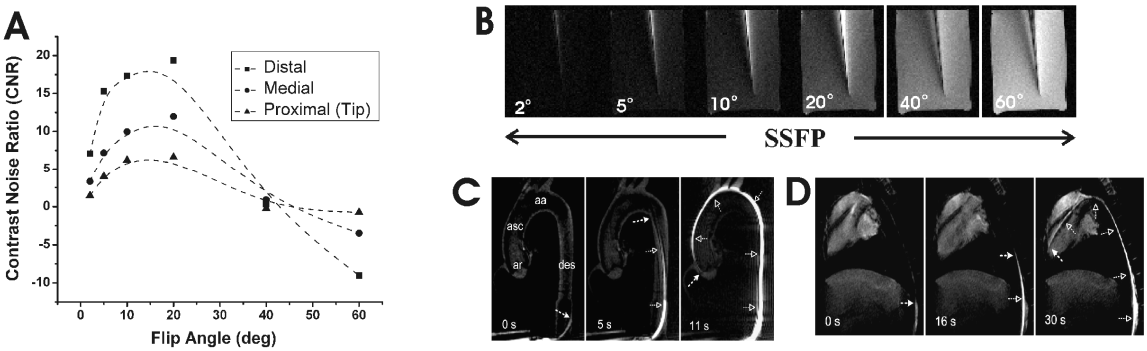

Fig A: The measured CNR values from distal, medial, and proximal (tip) portions of the guidewire as a function of flip angle (corresponding images shown in **Fig B**). Note that the CNR is positive for small α (≤ 20°) and is negative for $\alpha \geq 40°$, with the peak positive CNR around 20°. **Fig C**: Real-time LF b-SSFP images showing the passing of the guidewire from the aortic root (ar) and through the ascending aorta (asc), aortic arch (aa), and the descending aorta (des) within a aortic phantom. The guidewire's length (hollow arrows) and tip (white arrows) are visible. **Fig D**: LF b-SSFP images acquired in a live swine displaying the passing of the guidewire from the aorta into the left ventricle. The guidewire's length (hollow arrows) and tip (white arrows) are visible. Time following the commencement of image acquisition is given at the bottom left corner in Figs **C** and **D**.

Discussion and Conclusion Our initial studies showed that it is possible to visualize and track a conventional coronary guidewire with positive contrast using LF b-SSFP imaging within *ex-vivo* and *in-vivo* settings. These results also lend support to the hypothesis that LF excitations induce current in the guidewire augmenting the adjacent B_1 field to alter local flip angle and hence b-SSFP contrast. CNR values at the tip were significantly lower than in the medial and distal segments of the guidewire, likely due to current (and hence B_1 augmentation) falling to zero toward the tip, diminishing the effect. Additional studies are needed to evaluate the extent to which the current induced within the guidewires also leads to local tissue heating. In addition to the on-resonance local amplification of LF SSFP signals, it is also likely that positive contrast enhancements may also originate from off-resonance conditions established by the magnetic susceptibility shift between the guidewire and blood (3). Given the axial and length-wise asymmetry of signal enhancement surrounding the guidewire within the FOV, the primary source of signal enhancement is likely due to local on-resonance excitation. Direct measurement of current within the guidewire in the presence of LF excitation is necessary to confirm the actual source generating the positive signal enhancements surrounding the guidewire.

References (1) Quick HH et al, MRM 2005; 53:446; (2) Jackson JD. *Classical Electrodynamics* 1975 (3) Dharmakumar R et al., Phys Med Biol. 2006;51:4201.