Transient Steady-State Free Precession Coronary Vein MRI

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Introduction

Pre-procedural assessment of coronary vein anatomy is beneficial in transvenous cardiovascular procedures such as cardiac resynchronization therapy. We sought to develop a cardiovascular MR imaging methodology for imaging the coronary veins. Deoxygenated blood within the coronary veins may cause imaging artifacts due to increased B_0 field inhomogeneity [1]. Steady state free precession (SSFP) is commonly used in cardiovascular imaging due to its high signal-to-noise and contrast-to-noise ratios [2]. However, this sequence is sensitive to B_0 field inhomogeneity, a problem that is exacerbated in high spatial resolution imaging that requires longer TRs. Furthermore, the T_2/T_1 contrast of SSFP imaging [3] could yield reduced venous blood signal due to its shorter T_2 relative to arterial blood. In this study, we present preliminary results of the feasibility of SSFP coronary vein imaging with magnetization transfer (MT) compared with gradient echo.

Methods

A free breathing, vector ECG gated, coronary MR vein imaging sequence, analogous to the one used in the coronary artery imaging was developed (Fig. 1). The T_2 preparation pulse, used in coronary artery imaging, causes signal loss in the venous system due to short venous T_2. Thus, we used an MT sequence for contrast enhancement.

A 3D axial, low resolution scan was acquired for localization of the coronary veins. Subsequently, the volume for coronary vein MR imaging was prescribed. Images were acquired with both gradient echo-acquisition and SSFP imaging for each subject. The imaging parameters were as follows: Gradient echo: TE=1.9ms TR=6.1ms $\alpha=30^0$ spatial resolution of $1\times1\times3mm^3$ reconstructed to $0.53\times0.53\times1.5mm^3$, and SSFP: TE=2.7ms, TR=5.4ms, $\alpha=90^0$, 20 slices, spatial resolution of $1\times1\times3mm^3$ reconstructed to $0.53\times0.53\times1.5mm^3$, with 5 dummy RF pulses preceded by an $\alpha/2$. To measure off-resonance due to deoxygenated blood and the heart/lung interface, a B_0 field map was acquired at the same cardiac phase as the coronary vein image acquisition. This off-resonance field map was reconstructed by acquiring two 2D gradient echo images at different echo times (ΔTE = 2ms, spatial resolution $1.4\times1.4mm^2$) and calculating the phase difference for each pixel. Five 2D slices were acquired using the navigator for motion compensation.

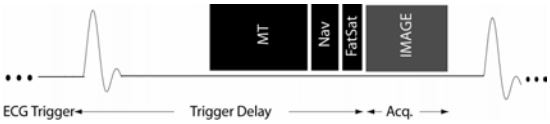

Figure 1: Coronary vein imaging sequence: a magnetization transfer (MT) preparation, consisting of 8-10 off-resonance RF pulses, is followed by respiratory navigator (NAV) and spectral selective RF for fat saturation (FatSat). A gradient echo or SSFP imaging acquisition composed of 10-15 imaging TRs is applied for image acquisition (IMAGE).

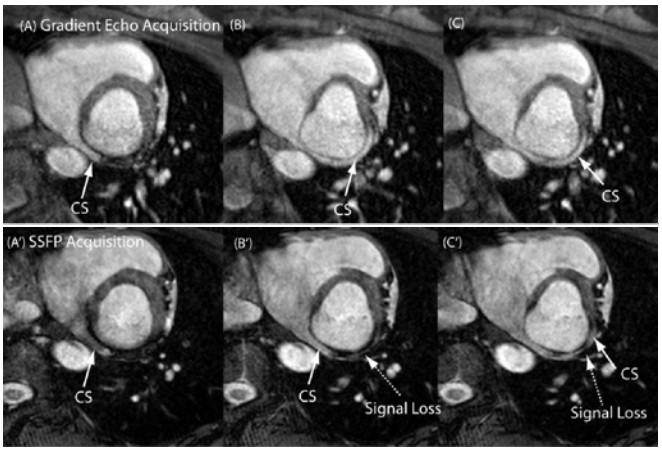

Figure 2: Three consecutive slices from a 3D data set of coronary sinus (CS, solid arrow) in a healthy subject, acquired with gradient echo (A-C) and SSFP (A`-C`). There is visible signal loss in SSFP images (dashed arrow).

Results

Fig. 2 shows three slices extracted from a 3D data set acquired with gradient-echo (A-C) and SSFP (A`-C`). There is visible signal loss along the coronary sinus as shown by dashed arrows. Imaging artifacts were seen in 3 out of 6 subjects. Fig. 3 shows a representative B_0 field map measurement, which shows changes in resonant frequency in the coronary sinus. Quantitative SNR and CNR measurements were not performed in this study due to differences in imaging parameters that could affect these measurements.

Conclusion

Coronary MR vein imaging with SSFP sequence is an alternative to gradient echo imaging but its sensitivity to local off-resonance could cause unwanted imaging artifacts and signal loss.

References

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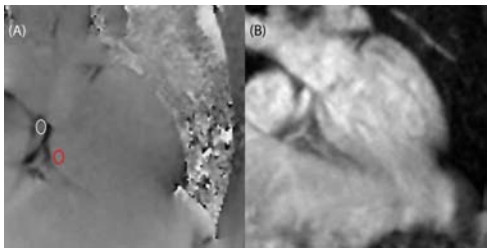

Figure 3: (A) B_0 field map and (B) corresponding anatomical location in a coronal scan in the posterior wall of the heart. The frequency off-set in the coronary sinus (white-solid circle) is 51±18 Hz, and in the neighboring myocardium (red-dotted circle) 4±4 Hz.