Improved Coronary MRA Using Wideband SSFP at 3 Tesla with Sub-millimeter Resolution

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Introduction With coronary artery disease being the leading cause of death in the western world, imaging the coronary artery lumen is one of the most important applications of medical imaging. MR coronary artery angiography is attractive because it is non-invasive and involves no harmful ionizing radiation. The combination of SSFP and 3T has been used to generate coronary artery images with higher SNR and blood-myocardium CNR compared to 1.5T [1]. However, conventional SSFP is sensitive to B_0 inhomogeneity and demands an imaging TR of 3.3 to 4 ms [2] to obtain reliable image quality at 3T. The need for a short TR makes it difficult to achieve sub-millimeter resolution given the current gradient hardware limits and peripheral nerve stimulation limits.

Alternating TR (ATR) methods have been recently developed as a means for modifying the spectral response of SSFP [3]. Wideband SSFP uses alternating TR and 0-π phase cycling to widen the band spacing and relax the 1/BW TR limitation [4]. It allows a flexible trade-off of the high SNR of 3T SSFP for an increased bandwidth, and has the ability to suppress off-resonance related banding artifacts in steady-state cardiac imaging for a desired spatial resolution.

In this work we present the design and application of a wideband SSFP technique for sub-millimeter resolution coronary artery imaging at 3T. We demonstrate that wideband SSFP provides a marked improvement in image quality and SNR, respectively, when compared to conventional SSFP and GRE sequences.

Method Experiments were performed on a Signa Excite HD 3T scanner (GE Healthcare, Waukesha, WI). Five healthy volunteers were scanned after providing written informed consent. Free-breathing coronary magnetic resonance images were acquired using three-dimensional respiratory navigated sequence that used either a wideband SSFP, conventional SSFP or conventional GRE acquisition. Sequence structure is shown in Figure 1. Trigger delay was individually selected to center the imaging window at mid-diastole. Right hemidiaphragm pencil beam navigator was inserted prior to the data acquisition in each cardiac cycle with a 4-mm acceptance window. After the navigator a spectral-selective fatsat pulse and dephaser gradient were applied. A 16-step Kaiser-Bessel ramp preparation was used to put magnetizations to steady states [5]. Localized shimming and center-frequency adjustment were performed to minimize off-resonance artifacts. Imaging parameters were: FOV = 26 cm, matrix size = 384 ×256 pixels (resolution = 0.68×1.0 mm^2), slice thickness = 1 mm, 16-20 slices, flip angle = 55º, TR = 3.9-4.2 ms. ECG gating was used with 26 k-space lines acquired in each heartbeat.

Results and Discussion Figure 2 shows representative 3-D reformatted LAD images with 0.68×1.0×1.0 mm^3 resolution. Wideband SSFP image was acquired in 5 minutes with navigator efficiency (Figure 2a). Figure 2b shows a conventional SSFP image with the same spatial resolution and TR (3.9 ms), where banding artifacts obstruct the assessment of vessels of interest. Wideband SSFP with TR/TRs = 3.9/2.4 ms is expected to have a 24% wider null-to-null spacing (~317Hz) compared to SSFP and this increased bandwidth removes the off-resonance artifacts from the region of interest.

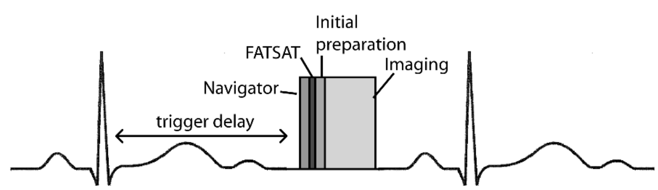

Figure 1. Pulse sequence for 3D coronary imaging. Image acquisition is centered at mid-diastole.

Conclusion We have demonstrated non-contrast high-resolution coronary artery imaging at 3T using wideband SSFP. The reduced sensitivity to field inhomogeneity permits a prolonged readout duration and a sub-millimeter resolution of 0.68×1.0×1.0 mm^3 was achieved.

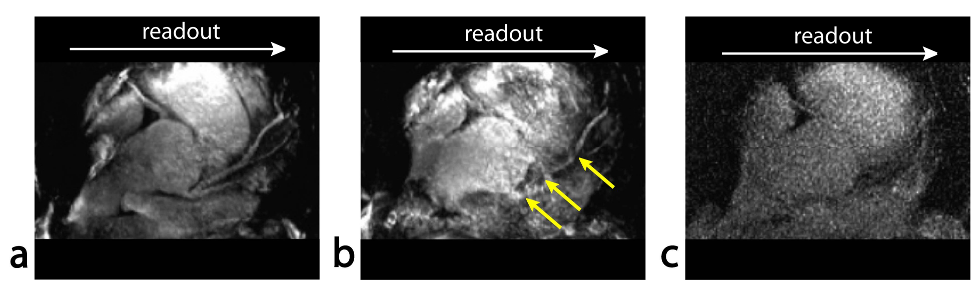

Figure 2. Coronary artery images with 0.68 ×1.0×1.0 mm^3 resolution. Imaging TR = 3.9 ms, flip angle = 55. (a) wideband SSFP, (b) conventional SSFP, yellow arrows indicate off-resonance artifact affecting the visilization of the vessel. (c) GRE image with substantially lower SNR.

References

[1] Stuber *et al.*, MRM, 2002; 48:425–429.
[2] Schär *et al.*, MRM, 2004; 51:799–806.
[3] Leupold *et al.*, MRM, 2006; 55:557–565.
[4] Nayak *et al.*, MRM, 2007, 58:931-938
[5] Lee *et al.*, ISMRM 2008 (submitted)