Three-dimensional Whole-Heart Cine MRI using Prospective Self-Gating for Compensation of Cardiac and Respiratory Motion

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Introduction:

Two-dimensional (2D) breath-hold and ECG-triggered cine MRI is frequently used to assess cardiac function. However this technique requires cooperation from the patient, and the MR acquisition has to be synchronized with the cardiac cycle using ECG. To control respiratory motion, the subject has to perform breath-holds or the position of the diaphragm has to be tracked using a respiratory navigator [1]. Despite those possibilities, cardiac and respiratory motion compensation can suffer from inaccuracies [2,3]. Prospective self-gating MRI [4] for simultaneous compensation of cardiac and respiratory motion represents a possible solution to overcome the problems associated with ECG-triggering and respiratory motion compensation. The aim of this study was to prospectively determine the accuracy of three-dimensional (3D) prospective self-gating MRI with compensation for cardiac and respiratory motion when assessing left ventricular (LV) and right ventricular (RV) function in the heart in comparison to standard 2D, multiple breath-hold SSFP cine imaging.

Methods:

Data were acquired in 20 subjects (10 healthy volunteers, 10 patients with suspected or known coronary and valvular heart disease) using a 1.5T system (Philips Healthcare, Best, The Netherlands) with a five element cardiac array coil. In each subject a standard multi-slice, multi-breath-hold 2D cine SSFP sequence (spatial resolution 1.4 x 1.4 x 8 mm^3, TR/TE/ flip angle 3.2 ms/ 1.6 ms/ 60°, 25 phases/cardiac cycle) was performed with complete ventricular coverage. Additionally, two 3D whole heart cine sequences (spatial resolution 1.4 x 1.4 x 8 mm^3, TR/TE/ flip angle 4.5 ms/ 1.7 ms/ 60°, 25 phases/cardiac cycle) with prospective self-gating were acquired. First, an ECG-triggered prospective self-gating sequence with free-breathing respiratory gating was acquired and. second, a prospective self-gating sequence with simultaneous compensation of cardiac and respiratory motion was performed. LV and RV end-systolic volume (ESV) and end-diastolic volume (EDV) and LV mass were calculated for each method. Image quality, based on the ability to identify the endocardial border, was scored on a five-point scale, (excellent visibility [5], mild blurring [4], moderate blurring [3], severe blurring [2] and non-diagnostic [1]).

Results:

There was substantial agreement between LVEDV, LVESV, LV mass, LVEF, RVEDV, RVESV, and RVEF calculated for the standard 2D and the two 3D prospective self-gating methods (concordance coefficients for ECG-triggered, respiratory gating: 0.99, 0.98, 0.99, 0.95, 0.99, 0.99 and 0.97, respectively and for simultaneous cardiac and respiratory compensation: 0.99, 0.99, 0.99, 0.98, 0.99, 0.99 and 0.97, respectively). Both 3D methods slightly underestimated all parameters compared to 2D (mean bias for each parameter was for ECG-triggered, respiratory gating: 1.8 ml, 0.9 ml, 0.1 g, 0.2%, 2.7 ml, 1.3 ml, 0.2 % respectively and for simultaneous cardiac and respiratory prospective self-gating: 2.1 ml, 0.6 ml, 0.2 g, 0.25 %, 2.1 ml, 0.4 ml, 0.7 % respectively). The overall image quality score for both prospective self-gating 3D acquisitions was lower when compared to standard SSFP (Figure 1). Figure 2 shows representative images from one patient.

Conclusion:

Three-dimensional, prospective self-gating MRI with ECG-triggered, free-breathing respiratory gating as well as with simultaneous cardiac and respiratory compensation enabled accurate assessment of LV and RV quantitative parameters when compared to standard multi-slice, multi-breath-hold SSFP cine imaging. Image quality with prospective self-gating was lower relative to the reference ECG triggered, multiple breath-hold scans due to lower image contrast between blood and myocardium and residual motion artefacts. Nevertheless, the technique holds considerable promise for scanning patients who are unable to hold their breath or small children with reduced compliance under sedation during MR examination.

References:

[1] Wang Y. et al. Magn Reson Med. 1995;34(1):11-96 [2] Shetty AN. Magn Reson Med. 1988;8(1):84-88 [3] Wang Y. et al. Magn Reson Med. 1995;33(5):713-719 [4] Buehrer M. et al. Magn Reson Med. 2008;60(3):683-90

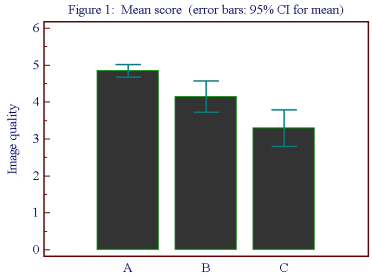

Figure 1: The mean visual image quality score A: multi-breath-hold, standard SSFP, B: ECG-triggered, free breathing prospective self-gating, C: Simultaneous cardiac and respiratory prospective self-gating.

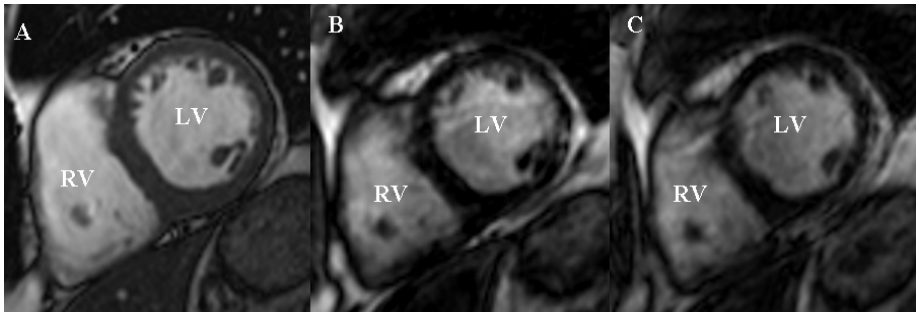

Figure 2: End-diastolic (ED) frame of the left and right ventricle (mid-ventricular slice in short-axis orientation); A: multi-breath-hold, standard SSFP, B: ECG-triggered, free breathing prospective self-gating, C: Simultaneous cardiac and respiratory prospective self-gating.