Retrospectively-gated, respiratory-triggered SSFP sequence for assessing LV function in freely-breathing pediatric patients

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Introduction: Compared to conventional fast gradient echo cine sequences, recently SSFP based cine has become the technique of choice for assessing LV function due to its higher intrinsic blood-to muscle contrast that is preserved throughout the cardiac cycle, high signal-to-noise ratio, and the symmetric gradient structure of the sequence provides more desirable flow properties [1,2,3]. SSFP techniques have been used in adults in a breath-held setting to assess LV function. However, SSFP sequences are sensitive to perturbations to the steady state either due to field inhomogeneities or bulk -motion, and the steady state has to be uninterrupted. Pediatric patients are often sedated and can not hold their breaths. The purpose of the study is to test the feasibility of using a steady state free precession (SSFP) sequence that uses retrospective cardiac gating and respiratory triggering to assess left ventricular (LV) function in freely-breathing pediatric patients. The sequence was optimized in volunteer studies, and initial results from 17 pediatric patients show that it is feasible to use this modified SSFP cine sequence to assess LV function in freely-breathing pediatric patients.

Materials and Methods:

MRI Data Acquisition: All imaging was performed on a Philips 1.5T Intera scanner. The cine SSFP sequence (balanced TFE) used had the following acquisition parameters: TR/TE/flip: 3.2 msec/1.6 msec/70°; temporal resolution: 40 msec/cardiac phase or better; acquired voxel size before zero padding 1.5-2.4 x 1.5 –2.4 x 8 mm; The sequence used a retrospective cardiac period of 1.3 cardiac cycles to ensure data collection throughout the cardiac cycle. A series of contiguous LV short axis slices were obtained to cover the entire LV. An external respiratory monitor triggered the data acquisition during end expiration with a user definable trigger delay. To minimize ghosting artifacts arising during the approach to steady state, in addition to the conventional $\alpha/2$ preparation pulse, dummy RF pulses were used before each segment.

Volunteer Study: The choice of flip angle, extent of oversampling of cardiac cycle required for retrospective gating, number of dummy RF pulses, flip angle and the choice of k-space sampling strategy were optimized In three normal, healthy adult volunteers.

Patient Study: The optimized SSFP sequence was used to assess the LV function in function in 17 pediatric patients breathing freely (15/17, sedated and 2/17 not sedated, age range: 5 months – 17 years; median age: 12 years, 14 males). The images were qualitatively evaluated for: motion artifacts (on a scale of 0:4, 0: none, 1: minimal to 4: severe), myocardium-blood pool contrast, and adequacy for quantitative LV functional analysis. LV function was evaluated quantitatively by drawing manual contours of endo and epicardial boundaries in diastole and systole.

Results: The volunteer studies revealed that a combination of a flip angle of 70°, dummy excitations of 3 per cardiac phase, a retrospective gating duration of 1.3 cardiac cycles, and a linear up-up profile order (i.e., adjacent cardiac phases same linearly increasing phase encoding steps) provided the best image quality. In patient studies, the heart rates varied from 51-123 bpm. Blood to myocardial contrast was excellent in all cases. A representative image is shown in Figure 1. Qualitative evaluation of motion artifacts showed that 9/17 patients demonstrated no noticeable motion artifacts, and 7/17 showed minimal motion artfacts that blurred myocardial margins, and 1/17 showed severe motion artifacts. Except the one patient who showed excessive motion artifacts, 16/17 SSFP data sets were considered adequate for quantitative evaluation of LV function.

Discusssion: In pediatric imaging, breath-holding is often not feasible. A commonly used strategy is multiple signal averaging to minimize the effect of respiratory motion. However, SSFP sequences pose special challenges in a pediatric population. First, the bulk motion during free breathing makes the tissues being imaged fall in and out of steady state introducing potential artifacts if the diaphragmatic excursion is significant, and secondly, the relatively large flip angles used in SSFP imaging makes cumulative RF dose a source of concern in a multi-phase, multi-slice, multi NSA acquisition. The alternative to multi-NSA acquisition is real time imaging. While this is useful, real-time imaging often makes tradeoffs in temporal resolution and/or spatial resolution. In addition, while real time imaging make it possible for qualitative assessment of LV function, quantitative assessment is often difficult. The combination of respiratory triggering, and retrospective gating addresses both these limitations. The disadvantage is the prolonged acquisition time, which on the average, was twice as long as a conventional untriggered acquisition.

Conclusions: It is feasible to use a SSFP sequence combined with respiratory triggering and retrospective cardiac gating to assess LV function in patients breathing freely thus benefiting from the higher myocardium to blood contrast, temporal resolution, and signal-to-noise ratio intrinsic to such SSFP sequences. In addition, this will eliminate the need for general anesthesia (substituted with sedation) for assessing LV function of young children.

References*:* 1.van der Meulen P. et al Magn Reson Imaging 1988; 6(4):355-368. 2.Plein S et al. J Magn Reson Imaging 2001; 14(3)230-236. 3. Carr JC et al. Radiology; 219(3):828-834.

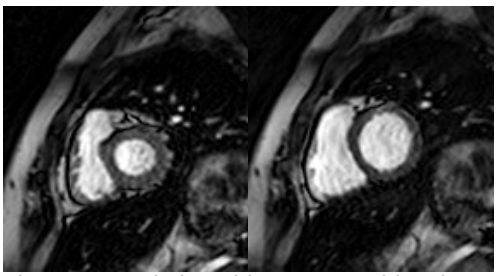

Figure 1. Freely-breathing16-year-old patient with leukemia and decreased ventricular function. Short axis end-systolic and end-diastolic views from restrospectively-gated, respiratory-triggered cine SSFP sequence.