REALTIME FREE-BREATHING UNGATED IMAGING OF CARDIAC FUNCTION AND VIABILITY USING AN IR-SPIRAL-SSFP SEQUENCE

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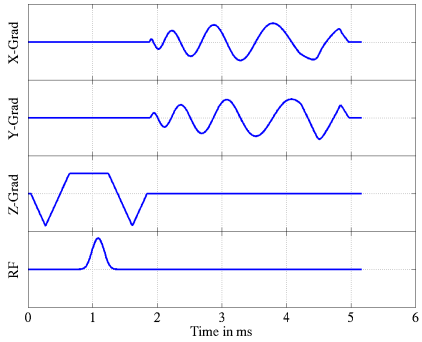
Introduction: Late-enhancement (LE) imaging has become the clinical mainstay of detecting the presence and extent of myocardial infarction. Typically this involves an inversion-recovery gradient echo (IR-GRE) sequence. These acquisitions require gating and repeated breath-holds, which are difficult to achieve in sick patients. Guttman et.al [1] had implemented a RealTime-Inversion-Recovery-SSFP (RT-IR-SSFP) method, which can be used for simultaneous observations of infarcted myocardium by LE, heart wall motion and the position of an MR-active interventional device. Detsky et.al [2] showed that this technique picks out infarcted areas, which are sometimes missed on the conventional DHE using IR-GRE. However the true temporal resolution is poor, due to view sharing between images, which can affect infarct visualization and wall-motion characterization. To alleviate this, we have implemented a spiral-based RT-IR-SSFP method, which gives us improved temporal resolution.

Methods: Following [3,4], we designed several spiral-SSFP based waveforms for different spatial and temporal resolutions. Figure-1 shows an example waveform, which has a Gaussian RF pulse, 586 gradient points during spiral readout, 4 us per gradient point, and 186 extra gradient points for nulling zeroth and first moments. A total of 16 interleaves over 30 cm field-of-view lead to effective spatial resolution of 3 mm, a TR of 5.5 ms and a true temporal resolution of 88ms.

We then incorporated this waveform and a hyperbolic-secant adiabatic inversion pulse in to our custom real-time setup on a 1.5T GE Twinspeed system. The sequence was asynchronous with cardiac rhythm, playing out the inversion pulse every 5 seconds, followed by the Spiral-SSFP sequence. A linear flip-angle preparation after inversion was also implemented to accelerate the transition to steady state after inversion. Four patients were scanned with this protocol, using an 8-channel cardiac array coil, 30 min after Gd-DTPA (Magnevist) injection. Figure-2 shows example images from one patient.



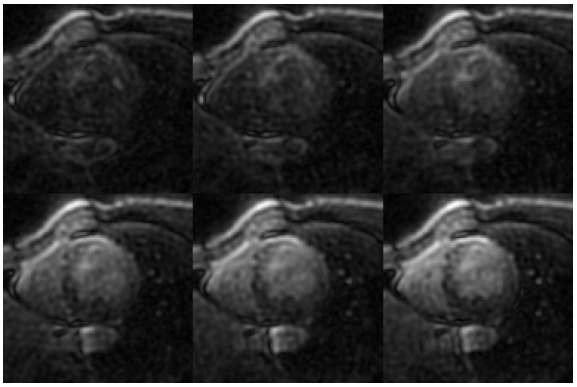


Fig-1 (Left): The pulse diagram for the 3mm spatial, 88ms temporal resolution waveform. It also includes intermittent adiabatic inversion pulse (not shown).
Fig-2 (Right): Shows successive view-shared reconstructed images from our custom realtime setup. The inversion times are about 250 ms for the first image, increasing by 60 ms for each successive image. The infarct can be seen in 10:00 to 12:00 position.

Discussion: We have demonstrated a high temporal resolution spiral based SSFP inversion recovery sequence, to be used in sick patients or in interventional studies to simultaneously evaluate cardiac function and viability. The spiral-SSFP waveform nulls the zeroth and first moments for all three gradients. In contrast, the Cartesian versions don't null the first moment along the encode direction. Thus the spiral waveform trades off some temporal efficiency for better flow compensation. Second, since the spiral samples centre of k-space on each view, the inversion contrast for short T1 tissue will be blurred in an image. However since the T1 of heart muscle after Gd injection, is on the order of 300 ms, our temporal resolution of 88ms seems to be sufficient to minimize this effect. Lastly, our low spatial resolution of 3mm blurs out the true extent of infarct. [Figures 2,3,4]. We expect the implementation of parallel imaging to improve tradeoffs between spatial and temporal resolution.

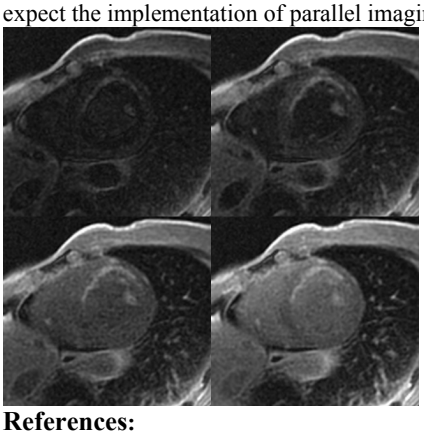
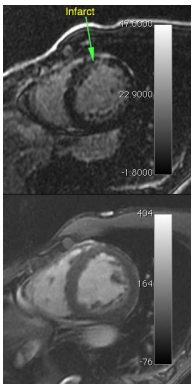


Fig-3 (Left): Images from the breathhold Gated-Cartesian IR-SSFP sequence [5] in the same patient and location as Fig-2. They have a 1.8 x 1.8 mm resolution and CINE interpolated over 20 phases over the heart cycle. The inversion times are approximately 200 ms, 245 ms, 290 ms, and 335 ms for the four images respectively.

Fig-4 (Right):
Top: An LE image using a regular IR-GRE sequence of the same patient and location. The resolution is 1.8 x 2.4 mm, inversion time is 200ms and 10 min after Gd injection.
Bottom: A regular SSFP image (no-inversion) at the same cardiac phase and location. It is CINE interpolated over 20 phases. The resolution is 1.4 x 1.6 mm.



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