32-Channel Real-Time MRI at ~50 Frames Per Sec For Irregular Heart Motion

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Introduction: The use of MRI for cardiac stress testing has been hampered by the need for ECG gating, which does not perform well under conditions of changing heart rate and/or irregular heart motion. Real-time MRI avoids this problem, but until recently has not enjoyed high enough frame rates to properly visualize heart motion under stress conditions. Techniques incorporating training data sets [1] can be used to increase frame rates, but these also can break down when heart motion becomes irregular. We have developed a 32-channel real-time cardiac MRI system and used it to image the heart at up to 48 effective frames per second during exercise stress testing, without the inclusion of training sets.

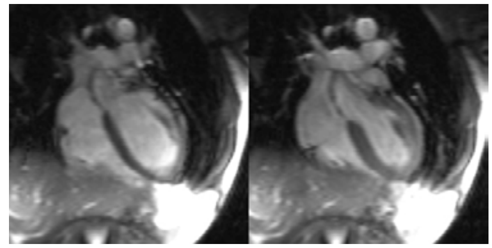

Fig 1. Diastolic and systolic frames from real-time 4-chamber data set acquired at 22 frames per second.

Methods: A 32-channel prototype GE MRI system was employed [2] to perform real-time imaging together with a 32-element cardiac receiver array [3]. The cardiac array comprised twenty-one 75 mm diameter circular elements mounted in a hexagonal array over the left-to-center chest wall and eleven 107 mm elements centered under the back. Custom imaging software was utilized to collect raw data from all 32 channels across multiple computers, reconstruct the images, and display them on the scanner monitor in real time. A main program directed the overall real-time application and provided the user interface, with controls to interactively change the scan plane [2]. A Beowulf cluster comprising eight nodes, each with dual 2.2 GHz AMD Opteron™ processors, has now been incorporated into this system as a real-time reconstruction engine, connected via private Gigabit Ethernet. Real-time imaging was performed using a FIESTA (balanced steady-state free precession) pulse sequence with a field of view of 33 cm, slice thickness of 8 mm, and TR of 2.8 ms. 128 readout points were collected, and 72 phase encodes with a half-Fourier acquisition scheme, using over-scans of 4 to 16 lines. ASSET acceleration factors between 2 and 4 were employed, along with a sliding reconstruction (slide factor of 2) to achieve effective imaging speeds of up to 48 frames per second. For accelerated imaging, low-resolution scans were first used to interactively move to the desired scan plane while collecting B1 field maps to calibrate the subsequent ASSET reconstruction. Switchover to accelerated imaging was achieved by a single button push on the user interface. Real-time scanning was performed on four normal volunteers, with exercise stress testing on a single volunteer.

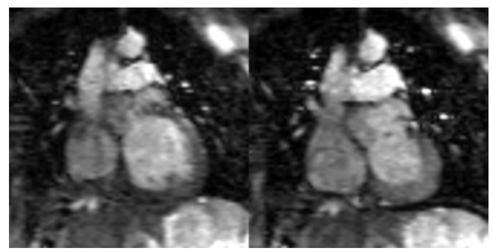

Fig 2. Diastolic and systolic frames from real-time coronal data set acquired at 44 frames per second

Results: Figure 1 shows still frames from a movie acquired at 22 frames per second in a four-chamber view of the heart. This used a x2 sliding reconstruction and an ASSET factor of two. Reducing the half-Fourier over-scans from 16 to 4 lines increased the effective scan rate to 31 frames per second, with some loss of SNR. Raising the ASSET factor to 4 with 8 over-scan lines resulted in frame rates of 44 frames per second, as exemplified by the coronal data set of Fig. 2. While the SNR is reduced relative to Fig. 1, the image quality is still sufficiently high to enable quantification of cardiac wall thickening. Figure 3 shows a plot of wall thickening versus time, measured on a 48 frame-per-second data set acquired immediately after exercise had increased the heart rate to an average of 85 BPM from a resting rate of 52 BPM in a normal volunteer.

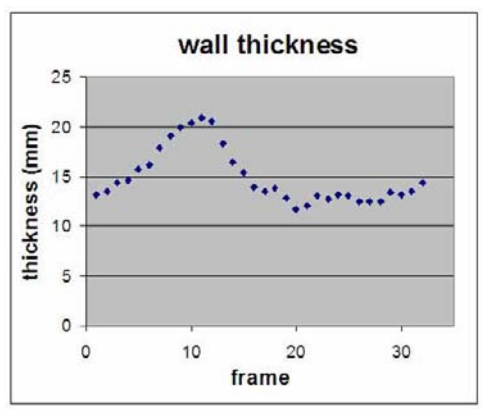

Fig 3. Plot of wall thickness versus time, taken from 48-frame-per-second data set.

Discussion: The use of 32 receiver channels has previously been shown to improve the SNR of breath held cardiac imaging [3], and has been implemented here to enable higher frame rates for accelerated real-time cardiac imaging. Effective frame rates of 48 frames per second have been achieved without the use of training data sets. This technique may also be useful for assessing beat-to-beat variations in contraction that differ dramatically in normal and stunned myocardium from that in non-viable myocardium after irregular heart beats.

References:

1. J Tsao, et al., Magn Reson Med 2003; 50:1031-1042.
2. CJ Hardy, et al., Magn Reson Med 2004; 52:878-884.
3. T Niendorf, et al., 13th ISMRM, 2005, p. 702.

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