Real-Time Single-Shot CINE Imaging of Through-Slice Strain in the Human Heart

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Introduction

For real-time monitoring of cardiac function it is desirable to measure wall strain of multiple cardiac phases in a single-shot. This can be done with DENSE (Displacement encoding with stimulated-echo)(1) cine imaging(2) of the through slice displacement of two contiguous slices. Reese et al. developed a BURST technique for 3D strain imaging which acquires two images from two slices in a single shot(3). However it requires multiple shots for all cardiac phases and the echo times of the two slices are different, which can result in off-resonance phase and strain errors. We developed a slice-interleaved segmented EPI cine sequence which acquires all cardiac phases in a single shot, with identical data acquisition for both slices.

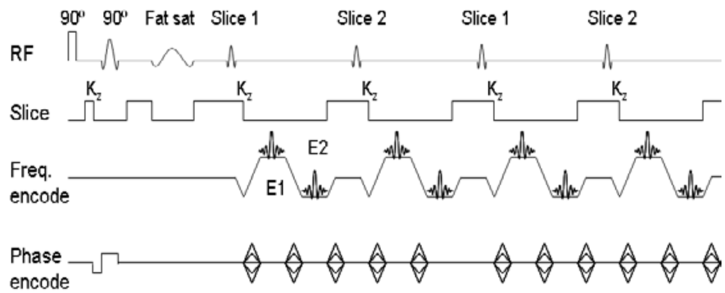


Figure 1

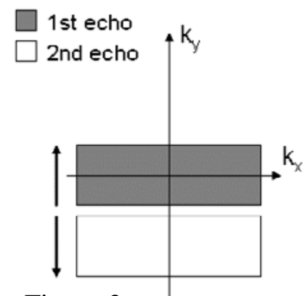


Figure 2

Method

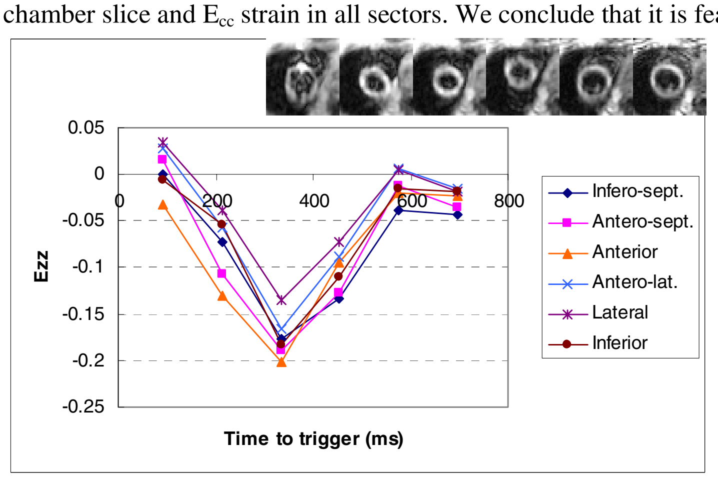
Scans were performed on a 1.5T system (Sonata, Siemens). The pulse sequence is shown in Fig.1. The second 90º pulse of spin preparation is selective in the phase-encode direction to limit FOV. A spectrally selective fat suppression pulse is played between spin preparation and image acquisition. Only encoding gradient in the slice direction is played, which also acts to crush the stimulated anti-echo and the FID echo from T_1 recovery. The sEPI gradient-echo acquisition has ETL of 2, and 40 k-space lines are acquired for each slice. Six cardiac phases of 120 ms duration are acquired, resulting in a total of 120 RF pulses in a single shot. The flip angles are ramped to equalize the echo amplitudes. A 2/3 partial k-space reconstruction is used. K-space filling uses a modified bottom up order (Fig. 2). Other parameters are: bandwidth = 1300 kHz/pixel, matrix size 60x128, FOV 300x640 mm^2, slice thickness d = 8 mm, Kz = 1.27 mm/radian. The through-slice strain of pixel (x, y) at time t is given by

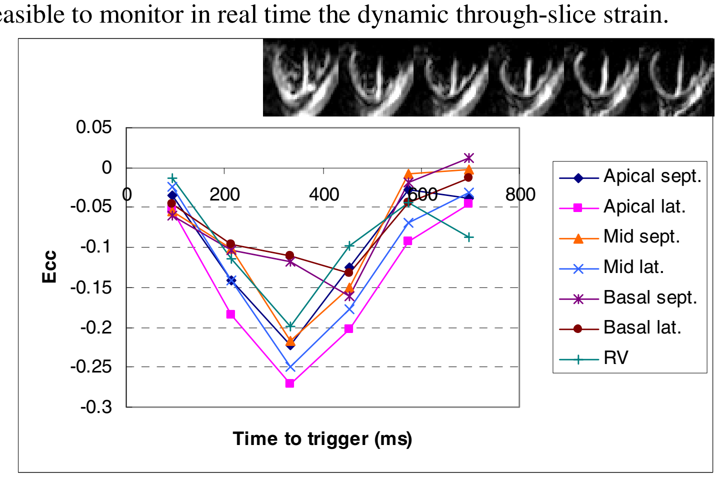
$$E_{TS} = \Delta\varphi(x,y,t)\cdot Kz/d,$$

where Δφ is the phase difference between the two slices. For optimal SNR when combining multiple receiver channels, Δφ is the phase of the slice-combined image(4) $I_c = \sum_n I_{1,n} I_{2,n}^{*} \left(|I_{1,n}|/|I_{2,n}| + |I_{2,n}|/|I_{1,n}|\right)$, where n denotes the receiver channel number.

Results and Conclusion

The data shown below were from a normal volunteer. The left panel shows the 6 cardiac phases of a heartbeat in a mid-level short-axis slice and the longitudinal (E_{zz}) strain in all sectors of the left ventricle. The right panel shows data from a long-axis 4-chamber slice and E_{cc} strain in all sectors. We conclude that it is feasible to monitor in real time the dynamic through-slice strain.





References

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