Robust and Efficient Whole Heart Black Blood Cine Imaging

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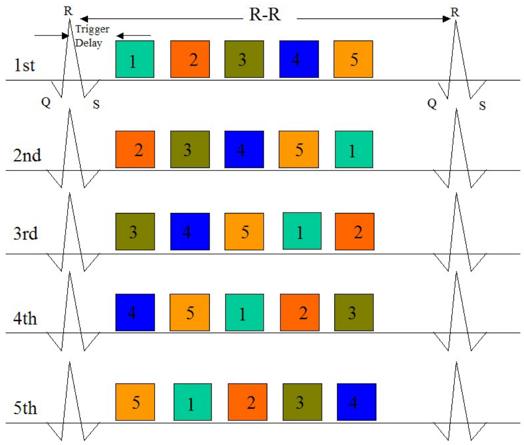
Introduction

Black blood imaging technique can be used to demonstrate excellent structural detail of cardiac morphology. The conventional black blood imaging method typically employed dual inversion pulse (DIR-BB) to suppress the signal from the blood pool[1]. The disadvantage of this technique is that each slice need to be imaged in separate breath-hold. Multi-phase DIR-BB has not been pursued due to poor temporal resolution and long acquisition time. The feasibility of obtaining faster multi-slice black blood images after administering the novel blood pool agent ferumoxytol have been demonstrated recently. The purpose of this study is to determine the feasibility of obtaining fast and efficient multi-slice cine black blood images using an interleaved rotating slice single shot fast spin echo imaging pulse sequence.

Materials and Methods



Studies were performed on a GE Healthcare SIGNA EXCITE Twin Speed 1.5T Whole Body Imager (Milwaukee, WI) using a 4 elements torso phased array coil. The contrast agent (ferumoxytol, Advanced Magnetics, Cambridge, MA, 4mg Fe/kg), which has a vascular half-life of 14 hours, was administrated intravenously at a rate of 15mg/sec over approximately 20 seconds. Healthy volunteer (n=1) and patients (n=4) with suspected vascular diseases were imaged as part of a phase II clinical trial. A cardiac-gated single shot fast spin echo pulse sequence was optimized to achieve shortest possible echo spacing to minimize blurring from cardiac motion. Typical imaging parameters were FOV=32-44cm, matrix size=160x128, TE =20-25msec, receiver bandwidth=+/-125 kHz, echo spacing=2.8-3.2ms, slice thickness=6-10mm, 5-10 slices to cover the entire heart. Partial parallel imaging (ASSET) with 2X acceleration factor was used to reduce the number of phase encoding step (ETL) to further minimize cardiac motion. Cardiac images were acquired post contrast in equilibrium phase. The acquisition time was between 80-100 ms per cardiac frame. Multiple slices were acquired across the whole R-R interval. The slices were rotated cyclically to sample different cardiac phase in different R-R interval. The acquisition can be repeated several more times with incremental trigger delay to acquire additional cardiac phases to improve effective temporal resolution (25-100ms). Figure 1 shows the schematic of the interleaved rotating slice acquisition techniques for acquiring 5 slices, 5 phases across 5 R-R interval. Depending on the patient heart rate, whole heart (5-10 slices) black blood cine (15-20 phases) can be obtained in as little as a single breath-hold (20 R-R interval).

Results and Discussion

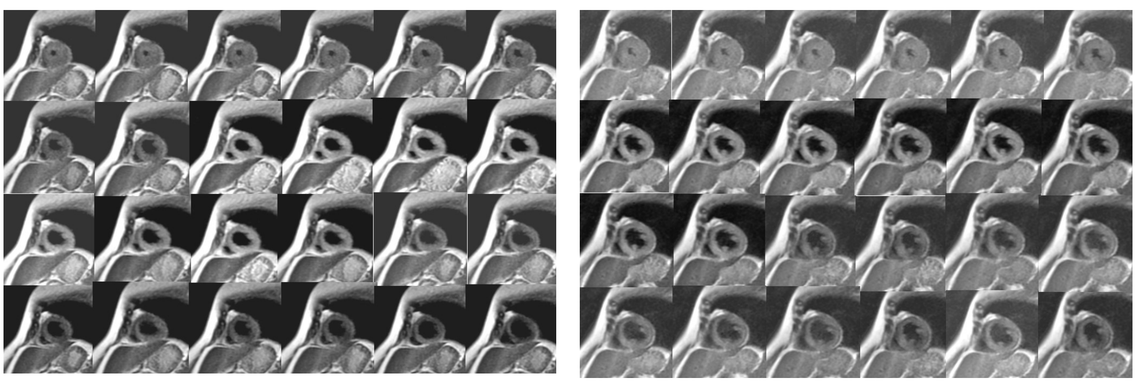


Figure 2 shows sample short axis black blood cine images at two locations from a patient with suspected vascular diseases. The effective temporal resolution is 25 ms. Intravascular signal intensity was completely absent for hours in the equilibrium phase after contrast administration; whereas, the myocardial signal remained high. There was excellent blood pool/myocardium contrast. Artifact-free black blood cine images with good delineation of endocardial contour were acquired in all subjects. Unlike the DIR-BB technique, rapid multi-slice cine imaging was feasible. The short acquisition time of the single shot FSE technique generally minimized blurring artifacts due to cardiac and respiratory motion. However, some artifacts still remain in the systolic phase probably due to cardiac motion that can be reduced once parallel imaging acquisition with higher acceleration factor can be employed. The current proposed techniques appears to be highly efficient as the data were acquired through out the cardiac cycle. Quantitative comparison of the proposed black blood cine technique with the standard GRE/SSFP cine imaging for cardiac function evaluation will be performed in the future in addition to further pulse sequence optimization to obtain higher resolution/quality images.

References

[1] Edelman, R.R. et. al., Radiology, 1991, 181:655-660.