IMPROVED 2D SLICE-INTERLEAVED FLOW-INDEPENDENT BLACK BLOOD CARDIAC IMAGING USING FERUMOXYTOL

Junfei Lu[1], J Paul Finn[2,3], and Peng Hu[2,3]

[1]*Department of Bioengineering, UCLA, Los Angeles, California, United States,* [2]*Department of Radiological Sciences, UCLA, Los Angeles, California, United States,* [3]*Biomedical Physics Inter-Departmental Graduate Program, UCLA, Los Angeles, California, United States*

Purpose: Double inversion recovery (DIR)[1,2] is the most commonly used black blood (BB) preparation method. However its single slice nature makes the acquisition inefficient and flow-dependence causes insufficient blood suppression when stagnant blood or in-plane blood flow is present. In this work, we propose to use ferumoxytol, an FDA approved iron oxide particle for treating iron deficiency anemia[3], as an MR contrast agent to achieve flow-independent BB imaging by taking advantage of its strong R2 relaxivity[4]. As our technique eliminates the need for DIR preparation, we propose to achieve higher scan efficiency by interleaving the imaging slices.

Methods: On seven healthy volunteers, we acquired 12 consecutive short axis (SA) slices covering the ventricles and 2 horizontal long axis (HLA) slices, both pre- and post- ferumoxytol injection on a Siemens 3.0T Trio scanner. Conventional ECG gated single-slice breath-held DIR Turbo Spin Echo (TSE) sequence was used for pre-contrast acquisition, with TR=2 R-R interval, TE=37ms, echo spacing (ESP)=5.25 ms, echo train length (ETL)=15, TI=600ms and breath hold duration=18s. Subsequently, ferumoxytol was injected (4 mg-Fe/kg) and the proposed BB imaging with three slice interleaved (Fig. 1) was performed after one minute. The elimination of DIR preparation enabled slice-interleaved scan where 12 SA slices were acquired in 4 breath-holds. TR, TE, ESP and ETL were kept the same for the post-contrast sequence. A TE of 37ms was found to be a good balance between suppressing blood signal and maintaining myocardium signal. SNR, CNR and sharpness (inverse of 20-80 % rise/drop) of the septal wall were quantified and compared using the pre- and post-contrast BB techniques.

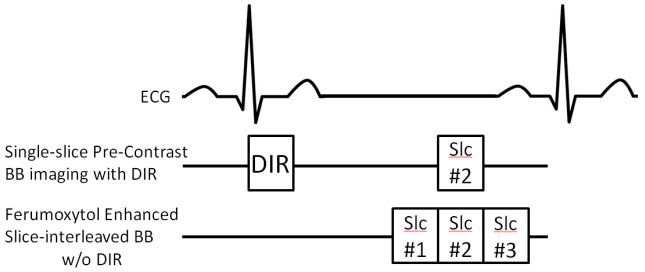

Fig. 1: Block diagrams for single-slice DIR TSE and slice-interleaved TSE without DIR. The removal of DIR pulses enables interleaved slice acquisition. The central readout ADC of the interleaved acquisition is located at the same cardiac phase as ADC in single slice scheme.

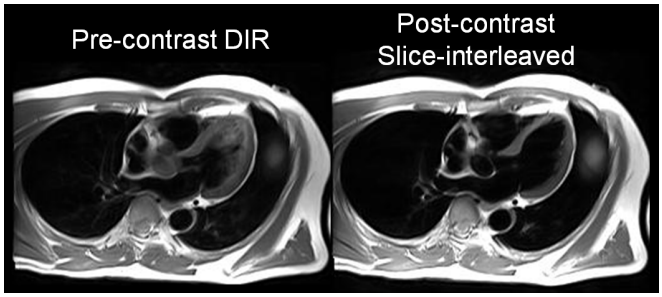

Fig. 2: HLA images of a healthy volunteer. The stagnant blood is evident in pre-contrast images near apex and endocardium. Whereas in post-contrast images, such residual signals are eliminated and myocardial walls are better delineated.

Results: In HLA view (Fig. 2), the stagnant blood was evident in pre-contrast images near apex and mid-ventricular myocardium; whereas in post-contrast images, such residual blood signals were eliminated in all volunteers. Figure 3 shows three interleaved SA slice from one acquisition. In basal and mid SA slices, both pre- and post- contrast images offered satisfactory black blood contrast. In apical slice, post-contrast image showed significant improvement in all 7 volunteers by eliminating stagnant blood signal. Average myocardial SNR and myocardium-blood CNR increase after ferumoxytol injection, especially for apical segments (SNR: 28.9±4.9 vs. 38.5±5.1, $P<0.0001$ and CNR: 6.2±8.13 vs. 22.6±6.4, $P<0.0001$). The pre- and post-contrast BB images have similar sharpness value ($r^2=0.95$).

Conclusions: Compared to conventional DIR BB imaging, the proposed ferumoxytol-enhanced slice-interleaved TSE technique provides improved blood signal suppression that does not depend on flow and is at least 3X faster than conventional DIR for the same anatomical coverage. It also provides higher SNR and CNR due to signal boost from ferumoxytol while maintains sharpness of the septal wall.

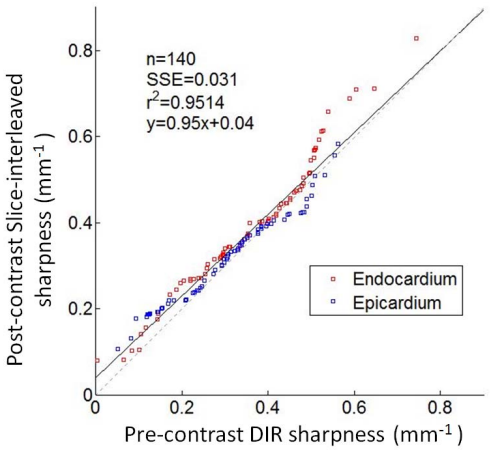

Fig. 4: Correlation scatter plot of myocardial wall sharpness measurement from pre- and post-contrast mid-ventricular SA slice. The pre- and post-contrast BB imaging have similar sharpness values (Sum of squared error=0.031, pearson r-value squared=0.95).

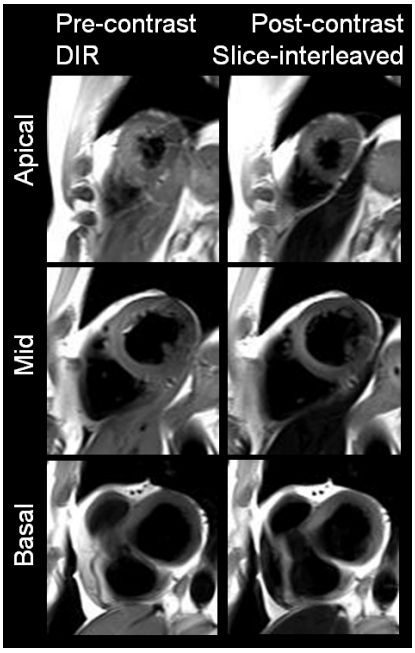

Fig. 3: Three SA images from one interleaved scan of a healthy volunteer.

References: [1] Edelman RR et al. Radiology 1991. [2] Simonetti OP et al. Radiology 1996. [3] Lu M et al. American journal of hematology 2010. [4] Corot C et al. Molecular and cellular MR imaging 2007.