LOcal excitation Black Blood Imaging (LOBBI) for local transmission coil at high field MRI (7T and above)

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Introduction: Efficient blood suppression is important for accurate plaque quantification in atherosclerotic plaque imaging. The current popular blood suppression techniques, such as double inversion recovery (DIR[1]) or motion-sensitized driven equilibrium (MSDE[2]), all rely on non-selective global spin excitation (DIR, MSDE) to achieve effective blood suppression. Should only local RF excitation be used, the efficacy of the blood suppression will become severely compromised because: 1) the in-flow of new, unsuppressed blood may replace the suppressed blood at the time of image acquisition; and 2) flowing blood particles may experience only a fraction of the whole preparation sequence, nulling the black blood (BB) effect. In reality, both effects may contribute to signal formation, leading to insufficient blood suppression. The recent trend of using higher magnetic field (7T and above) to achieve improved SNR and unique contrast, however, limits the application of BB imaging because local transmitted T/R coils are more frequently used in such systems due to the lack of volume coils and/or due to B_1-uniformity problems at high fields. As a result, for applications like carotid artery imaging, no effective BB imaging techniques is currently available at higher field. In this study, a LOcal excitation Black Blood Imaging (LOBBI) technique is proposed to achieve sufficient blood suppression using a local T/R coil.

Methods: Pulse sequence: the LOBBI pulse sequence is shown in Fig.1. The essence of this sequence is to suppress blood signal, by destroying its phase coherence similar to MSDE but after it is excited by the RF pulses. By doing so, the time gap between the blood suppression and data acquisition is greatly shortened, thus minimizing the in-flow effects. The bipolar motion-sensitizing gradients were placed only in the z-direction and repeated twice to minimize the eddy current effects on phase encoding and data acquisition directions, as suggested by a previous study[3]. This technique is compatible with a variety of pulse sequences commonly used in clinical scans, such as SPGR, SE or SSFP. When combined with the SPGR sequence, the signal drop caused by the motion-sensitizing gradients will not accumulate between TRs since the RF is selective and the signal will be spoiled at the end of each TR. This further improves the applicability of the LOBBI sequence, making it more suitable for repetitive black blood preparation, compared to the non-selective approach [2].

MR imaging: All images were acquired on a clinical 3T MR scanner (Philips Achieva R2.61, Best, the Netherlands) with a T/R head coil. Although the images were not acquired using a high field scanner (due to unavailable resources), the concept of the technique can still be tested since a local T/R coil is used for data acquisition.

Flow phantom imaging: The feasibility of the technique was tested on a flow phantom. A long tube with flowing water (v=80cm/s by PC MRI) driven by a water pump was used to simulate the blood flow in the artery, and a static water phantom was placed next to the tube to serve as a reference. A regular SPGR sequence was used to acquire data for the reference. The imaging parameters were: TR/TE 50/3.8ms, FA 20º, FOV 160 ×160mm^2, pixel size: 0.6×0.6mm^2, slice thickness 5mm, TFE factor: 6, fat saturation. The LOBBI sequence was applied with the same parameter except the effective TE becomes 11.8ms due to the addition of motion-sensitization gradients. For comparison purposes, DIR and MSDE images were also acquired with matched imaging parameters.

Results: Both the water flow and the static phantom can be observed in the baseline image (Fig. 2a), and the flow direction of the water tube was perpendicular to the axial imaging plane. In all three BB sequences tested, neither the DIR (Fig.2b) nor the MSDE (Fig.2c) sequence suppressed the flow signal, due to the in-flow effect. Only the LOBBI sequence suppressed the flow effectively, as indicated by the open arrow in Fig.2d. Quantitatively, the SNR of the tube from both DIR and MSDE were comparable to the baseline, indicating the insufficient blood suppression; the tube SNR from the LOBBI image is significantly lower (Fig.3). The CNR (SNR_{stat}-SNR_{flow}) was highest with LOBBI although SNR_{stat} of LOBBI was decreased due to increased TE (Fig.3).

Conclusion: In this study, a LOcal excitation Black Blood Imaging (LOBBI) sequence was proposed for effective blood suppression in high field MRI with local T/R coil. Among all tested BB techniques, the LOBBI sequence was found to be the only technique that can suppress flow signal when a local T/R coil is used. The LOBBI technique can also provide improved blood suppression in scenarios when the RF coverage is limited by the field inhomogeneity, esp. when long RF pulses with narrow bandwidths are used. LOBBI provides the maximum CNR among the tested BB techniques and is the best suited for plaque imaging at high field imaging with local transmit coils.

References: 1. Edelman RR, et al. Radiology, 1991. 2. Wang J, et al. MRM, 2007. 3. Wang J, et al. JMRI, 2010.

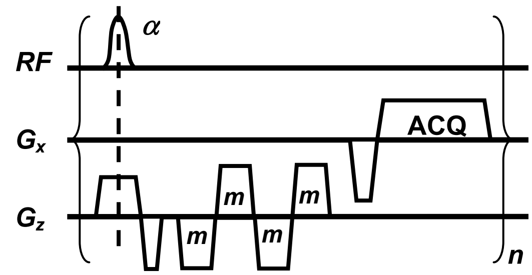

Fig.1 The pulse sequence of the LOBBI technique. Flowing blood will be suppressed by the motion-sensitizing gradients (trapezoids with 'm') after the selective RF excitation. The motion-sensitizing gradients are positioned right before the acquisition gradients (ACQ) to minimize in-flow effects.

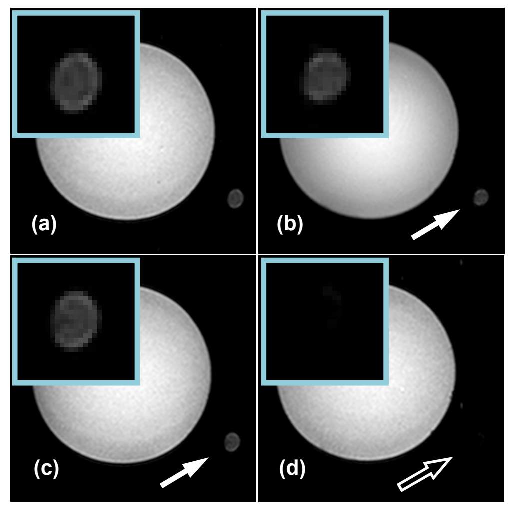

Fig. 2 Flow suppression efficiency comparison among different techniques: baseline (a), DIR (b), MSDE (c) and LOBBI (d).Notice the unsuppressed flow signal on DIR and MSDE images (arrows and zoomed images). The signal has been completely suppressed on the LOBBI image (open arrow).

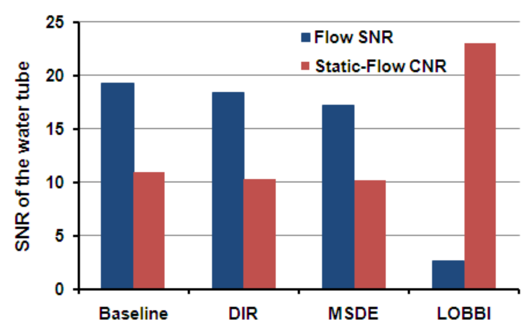

Fig.3 SNR comparison among the different flow suppression techniques. As the tube SNR and CNR indicated, LOBBI provides the most sufficient blood signal suppression compared to DIR and MSDE.