Flow-Independent T2-Prepared Inversion Recovery Black Blood MR Imaging

C-Y. Liu[1,2], O. Wieben[1], J. H. Brittain[3], and S. B. Reeder[1,2]

[1]Medical Physics, University of Wisconsin-Madison, Madison, WI, United States, [2]Department of Radiology, University of Wisconsin-Madison, Madison, WI, United States, [3]MR Applied Science Laboratory, GE Healthcare, Madison, WI, United States

Introduction "Black-blood" methods suppress blood signal to differentiate lumen from myocardium or vessel wall and are commonly used for morphometric cardiac[1] and atherosclerotic plaque[2] imaging. Double-inversion recovery (DIR)[3] is the most commonly used black-blood method. DIR relies on the inflow of nulled blood, and consequently, it is less effective in the presence of slow-flow or in-plane flow. To address this problem, we present a new flow independent black-blood preparation scheme that employs a T_2-preparation sequence[4] in combination with a non-selective inversion recovery pulse (T_2Prep-IR[5]). In-vivo examples of both through- and in-plane cardiac flow and carotid artery images are presented to demonstrate the effectiveness of this technique.

Theory The T_2Prep-IR pulse sequence consists of a T_2 preparation sequence followed immediately by a nonselective adiabatic inversion pulse. Data are acquired after an inversion time, TI, which is chosen to allow suppression of signal from blood while the T_2-preparation duration, TE_{eff}, determines the T_2-weighted contrast. Fig. 1 shows the simulated signal response of blood (T_1/T_2 =1200/220ms) and muscle (T_1/T_2 =900/35ms[5]) using IR only and T_2Prep-IR with TE_{eff}=70ms. Because the T_2 of blood is longer than that of muscle/tissue, T_2 prep will suppress the muscle prior to inversion. After the IR pulse, the myocardium/vessel wall will recover to a higher longitudinal magnetization Mz prior to the acquisition window, improving image SNR compared to IR alone. The blood signal is darker than that of muscle over a wide range of TI (after TI>250ms) and the blood-muscle contrast becomes insensitive to TI after the null point for blood. Hence, a black blood contrast can be achieved robustly in a flow independent manner, with high SNR in the surrounding muscle or vessel wall.

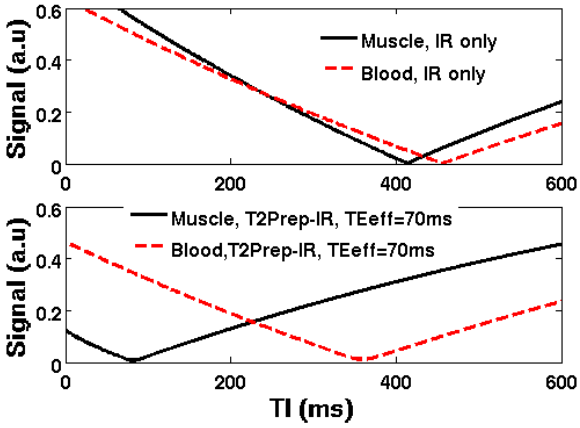

Fig.1 Simulated T_2Prep-IR signal response of muscle and blood using IR only and T_2Prep-IR with TE_{eff}=70ms.

Methods: T_2Prep-IR preparation was incorporated into the fast spin echo (FSE) acquisition sequence clinically used for black blood imaging at our institution. Experiments were performed on volunteers on a 1.5T GE Signa HDx scanner with approval from our IRB and after obtaining informed consent. T_2Prep-IR and standard DIR images were acquired at identical slice locations and with identical imaging parameters. For cardiac imaging, parameters included: ECG-gating, TE=41ms, Echo train length (ETL)=32 acquired every other heart beat, slice=8mm, FOV=350mm, 256x256 matrix, bandwidth=±62.5kHz, using an eight-channel phased array cardiac coil, and one slice per breath-hold. Parameters for carotid imaging included: no gating, TR/TE=800/10ms, ETL=10, slice/FOV=3/160mm, 256x256 matrix, bandwidth=±20.83, using a single channel anterior neck coil. Six transverse axial images and one in-plane view of the carotid bifurcation were obtained for each preparation. The number of averages was adjusted to ensure equal scan times for the two acquisitions. TE_{eff}=70ms and TI=400ms were used in acquiring all T_2Prep-IR images. Blood suppression was qualitatively compared between two preparations in normal volunteers.

Results: Fig.2 shows cardiac images acquired with DIR and T_2Prep-IR preparations. The blood suppression is more consistent with T_2Prep-IR for the in-plane flow (4-chamber, the same window level for both images). However, higher contrast between blood and myocardium is achieved on the DIR short-axis image (lower window level was used for displaying T_2Prep-IR image). Fig.3 shows carotid images with flow artifacts on the DIR images (arrows, Fig.3a, c) that are completely removed with T_2Prep-IR preparation (Fig.3b, d). Also, note the suppression in the jugular veins. The same window level was applied for each set of images, indicating very good SNR performance of the carotid T_2Prep-IR images.

Discussions: We have demonstrated a new approach to achieve flow independent black blood suppression. The preparation is non-slice selective and independent of flow direction and velocity. Black blood suppression with T_2Prep-IR is particularly effective for in-plane flow suppression, compared to the DIR method. The main limitation of T_2Prep-IR is the reduction of muscle signal which can be compensated by longer inversion times while preserving the blood-muscle contrast. Clinical evaluation with patients is needed for further validation of this method.

Acknowledgements We thank GE healthcare for their support.

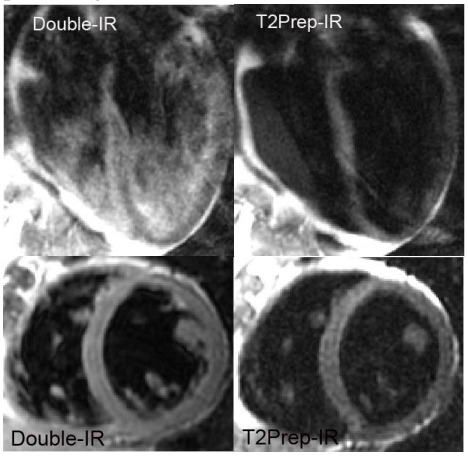

Fig. 2 Black blood images of four-chamber (top) and short-axis (bottom) views acquired using Double-IR and T_2Prep-IR preparations. T2Prep-IR gives consistent performance for blood suppression regardless of flow directions.

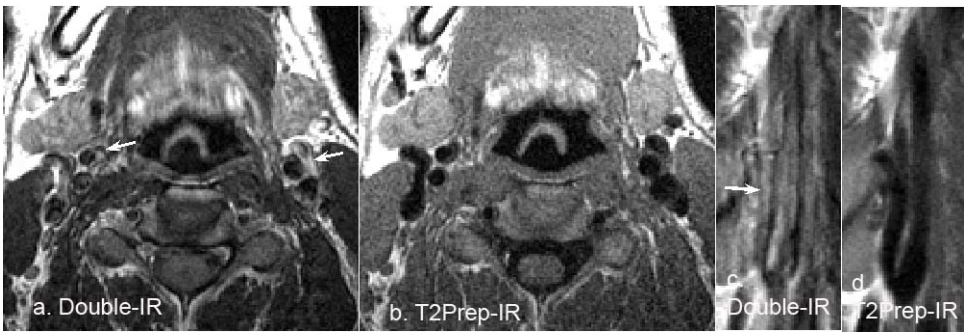

Fig. 3 Images of normal carotid arteries obtained with different preparations. Flow artifacts (white arrows) seen on Double-IR image (a, c) are not present when T_2Prep-IR preparation is used and uniform blood suppression was achieved for both, through- (b) and in-plane (d) flows.

Ref [1] Vignaux OB, et al. Radioloy. 2001:219:545-550. [2] Yarnykh VL, et al. MRM. 2006;23:691-698. [3] Edelman RR, et al. Radiology. 1991;181:655-660. [4] Brittain J, et al. MRM. 1995;33(5):689-96. [5] Brittain J, et al. MRM. 1997;38(3):343-54.