

T2 Mapping to Differentiate Slow Flowing Blood from Vessel Wall

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INTRODUCTION

Vessel wall MRI commonly employs double inversion recovery (DIR) preparation to suppress blood signal (1). DIR blood suppression is excellent when blood velocity is high but may be compromised when velocity is reduced or triphasic as in the lower extremities. In this study, T2 mapping was utilized to distinguish artifactual partial blood signal from vessel wall signal at three vessel sites with different flow characteristics. Further, to determine the effect of DIR partial blood signal on vessel wall area measurement, a flow-insensitive blood suppression preparation was implemented for comparison.

IMAGE ACQUISITION

The descending aorta, common femoral and popliteal arteries were imaged in 13 volunteers (7 male, 6 female, age=34±13years) at 1.5 T. DIR preparation was followed by a multi-echo fast spin echo (FSE) readout (TE ranging from TE₁=9.4ms to TE₁₀=347ms with 37.6ms TE spacing, 4 consecutive readouts per TE and 9.4ms echo spacing). For comparison, a T2 prepared inversion recovery FSE sequence (T2IR-FSE) was implemented with a 120ms T2 preparation followed by a TI=425ms wait time to null blood while maximizing vessel wall signal (2,3). Aside from TI, imaging parameters for DIR-FSE and T2IR-FSE acquisitions were identical: FOV=12cm (popliteal, femoral), 26cm (aorta); acquisition matrix=256×256 (popliteal, femoral), 512×256 (aorta); TR=2R-R intervals; slice thickness=4mm (popliteal, femoral), 6mm (aorta); NEX=3; and receiver bandwidth=31.5kHz. Electrocardiographic gating was used for cardiac synchronization. A spectrally selective prepulse was used to suppress fat signal. Acquisition time was 6.5 min for a heart rate of 60 bpm. 2D phase contrast (PC) imaging was also performed to measure blood velocity.

IMAGE PROCESSING

To determine vessel wall area, an experienced radiologist manually outlined the wall boundaries in TE₁ images. In DIR-FSE images, pixels were classified as either vessel wall or partial blood. Classification was based on the premise that in vivo vessel wall T2 is 48.2±7.4ms at 1.5T (4), leading to an estimation of 70ms for the maximum expected T2 value. Based on the exponential decay model, less than 4% of the original vessel wall magnetization remains at TE₇=234ms. Therefore, pixels with intensity less than the noise threshold ($\mu_{\text{noise}} + 3\sigma_{\text{noise}}$) at TE=TE₇ were deemed vessel wall, while others were considered partial blood. Pixel-wise T2 mapping was then performed by fitting the signal intensities to a mono-exponential decay model. An additional step was performed to refine pixel classification whereby collective T2 statistics were calculated for pixels initially classified as vessel wall. Pixels with T2 greater than the mean T2 value plus twice the standard deviation were reclassified as partial blood. This step prevented pixels with long T2 and low intensity from being classified as vessel wall.

RESULTS

Artifactual slow flow signal was observed in DIR-FSE images of the popliteal artery, evidenced by the rim of pixels along the wall-lumen boundary at TE=234ms and corresponding long T2 values (Fig. 1). Superior blood suppression was observed in T2IR-FSE images indicated by the lack of artifactual partial blood signal in long TE images and by T2 values within the expected range for vessel wall. A data set from a subject with no sign of arterial disease shows good blood suppression in the aorta, adequate suppression in the femoral and poor suppression in the popliteal (Fig. 2). The characteristic DIR slow flow artifact in the popliteal artery yielded a 21% overestimation of wall area compared to the T2IR-FSE derived area. In 11 of 13 subjects, DIR-FSE popliteal wall area measurements were greater than T2IR-FSE area measurements, while differences in aortic and femoral wall area measurements showed no clear trend (Fig. 3). Fig. 4 shows DIR-FSE partial blood pixels were most prominent in popliteal images, consistent with reduced blood velocity (Table 1). Finally, the DIR-FSE pixel classification correctly identified pixels as either vessel wall with T2 values in the expected range, or partial blood with substantially longer T2 values (Table 1).

CONCLUSION

T2 mapping was used to show that DIR blood suppression may be inadequate for vessel wall imaging in the popliteal artery where blood velocity is reduced at rest, resulting in inflated vessel wall area and T2 relaxation measurements. T2IR provided flow insensitive blood suppression and may be more appropriate for peripheral vascular wall imaging.

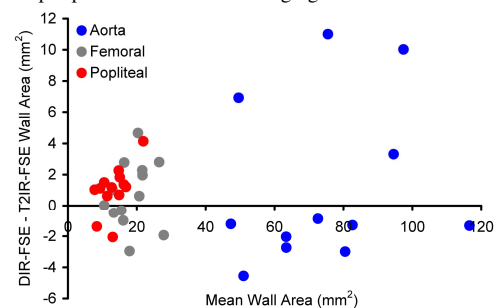


Fig. 3. DIR-FSE versus T2IR-FSE wall area measurement comparison. Agreement was 1.1 ± 5.1 , 0.7 ± 2.1 , and $1.0 \pm 1.5 \text{ mm}^2$ for the aorta, femoral and popliteal. The paired t-test showed a significant difference in popliteal wall area ($P < 0.05$), while differences in aortic and femoral areas were negligible.

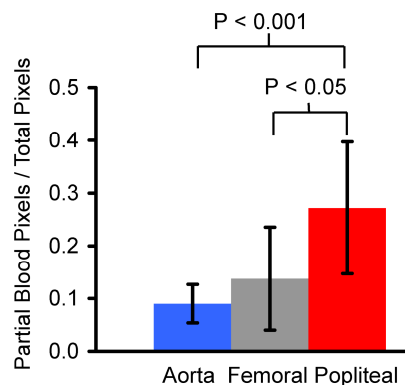


Fig. 4. Ratio of partial blood pixels to total pixels in segmented DIR-FSE images.

Table 1	Aorta	Femoral	Popliteal
DIR-FSE: T2 of vessel wall pixels (ms)	64.9 ± 10.3	54.2 ± 13.3	48.3 ± 6.5
DIR-FSE: T2 of partial blood pixels (ms)	127.4 ± 31.4	107.0 ± 35.3	95.3 ± 24.4
PC: Peak blood velocity (cm/s)	72.3 ± 16.5	43.1 ± 9.4	26.6 ± 5.4
PC: Stroke volume (mL/heartbeat)	57.3 ± 15.2	7.7 ± 3.7	1.4 ± 1.0

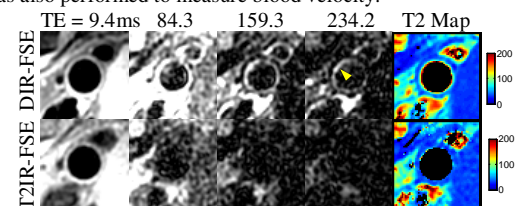


Fig. 1. DIR-FSE and T2IR-FSE popliteal images and T2 maps. Incomplete DIR blood suppression (arrowhead) is seen at the wall-lumen boundary. Window settings for the first echo are adjusted for visualization of the vessel wall, while settings for the remaining echoes are identical and adjusted to highlight DIR partial blood signal.

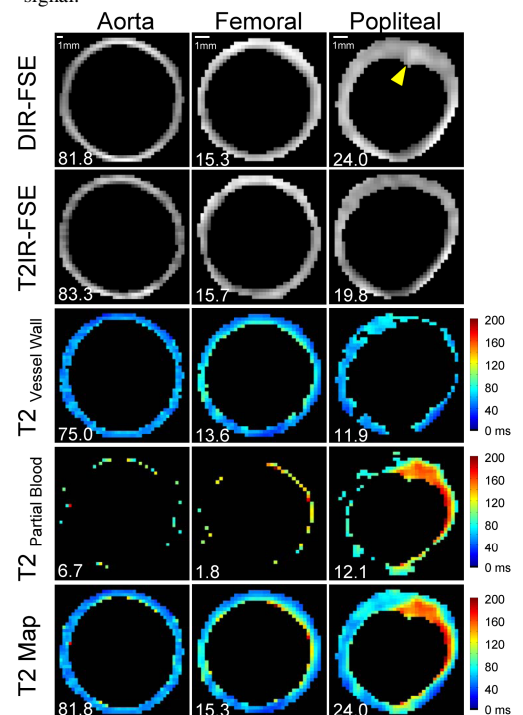


Fig. 2. Representative data set. Inadequate DIR blood suppression (arrowhead) resulted in inflated wall area and T2. T2 maps are derived from DIR-FSE images. Areas in mm² are inset. Cropped aortic images are 23×23mm², while femoral and popliteal images are 9×9mm².

REFERENCES 1. Edelman, et al. Radiology 1991. 2. Brittain, et al. MRM 1997. 3. Wong, et al. MRM 2001. 4. Toussaint, et al. Circ 1996.