Diffusion-Weighted Imaging Improves the Quantification of Myocardial Oxygenation when Arrhythmias are Present

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Purpose

We have recently shown that blood-oxygen-level-dependent (BOLD) T2-weighted images can determine the myocardial oxygen extraction fraction (OEF) during hyperemia [1,2]. This method works well using a double-inversion-recovery-pulse (DIR) prepared black-blood sequence. However, when irregular EKG-triggering or arrhythmias occur, for instance, during Dobutamine hyperemia, it is difficult to adequately suppress blood signal. The purpose of this study is to evaluate another black-blood imaging technique, a so called diffusion-weighted (DW)-prepared sequence [3], for its capability to determine the myocardial T2 and then quantify OEF in a stenotic dog model.

Methods

Eight dogs were divided into three groups (Table). Stenosis was created using an occluder in the proximal left anterior descending coronary artery (LAD). Myocardial black-blood T2-weighted images were acquired using a 2-D segmented DIR prepared turbo spin-echo (TSE) sequence. DW prepared T2-weighted images were collected with optimized sequence parameters. These sequences were performed several times during rest, and during either Dipyridamole or Dobutamine. Using a two-compartment model [1], the hyperemic OEF can be determined. Rest OEF was assumed to be 0.6, which is based on OEF values measured in normal dogs using an arterial and coronary sinus blood sampling approach at rest [1]. It is assumed that this value changes little with moderate stenosis [4,5]. In addition, myocardial blood volume (MBV) values, both at rest and during hyperemia, were determined with a quantitative first-pass perfusion MRI method. Regional T2 and MBV values were determined in the stenotic LAD subtended region and the remote normal left-circumflex (LCX) subtended region. Both data were used in the model to calculate regional OEF during hyperemia.

Table. Dog groups.

Group (*n*)	Stenosis	Stressor
1 (2)	90%	Dipyridamole
2 (3)	50%	Dobutamine
3 (3)	70-90%	Dobutamine

Results

Overall, there was no significant difference in the T2 values obtained by DW and DIR methods; although DW T2 was slightly less than DIR T2. This resulted in a non-significant difference in regional myocardial OEF between the two methods (Figure 1). However, Group 3 dogs with 70-90% LAD stenosis during Dobutamine-induced hyperemia showed a significant difference in regional OEF between the DW and DIR methods. Severe stenosis and increased heart contractility in this group of dogs lead to highly irregular heart rhythms. The OEF derived from the DW method seems to agree with the traditional wisdom that in the critical stenotic region, limited blood flow (O_2 supply) leads to an increase in OEF due to the elevation of MVO_2 (O_2 demand). In the normal regions, one would expect the increase in blood flow approximately matched the increase in MVO_2, resulting in no significant change in OEF. Figure 2 shows examples of myocardial T2-weighted images with both black-blood methods.

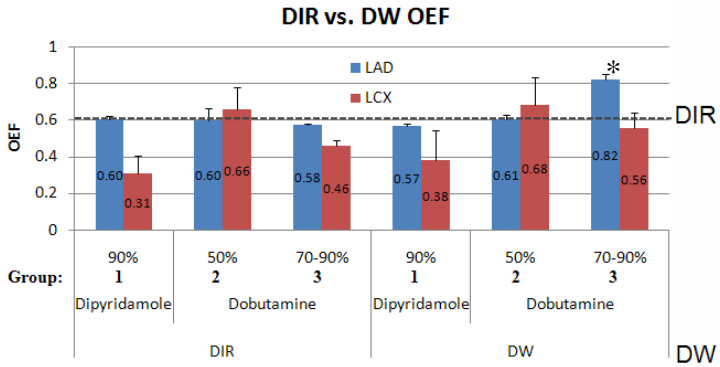

Figure 1. DIR and DW OEF during hyperemia with various stenosis degrees. The dotted line shows the assumed rest OEF of 0.6 .

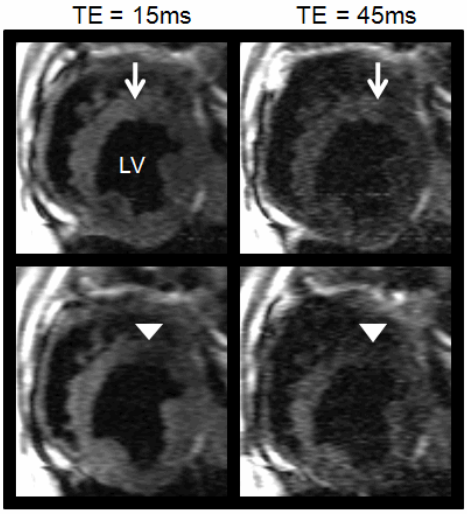

Figure 2. Comparison of DIR and DW prepared T2-weighted images during Dobutamine hyperemia in a LAD stenotic dog. Although blood signal in the left ventricle appears to be suppressed, the irregular ECG triggering and fast heart beats (~180/min) resulted in "spillover artifacts" from unsaturated blood signals, as shown in the anterior regions of DIR images (hyperintensity, arrows). DW images demonstrate the expected lower signals in the anterior regions (arrowheads) resulting from 90% LAD stenosis. LV = left ventricle.

The disadvantages of the DW method are the lower SNR (6.6 ± 2.1% lower) compared with DIR images, as well as an increased sensitivity to magnetic shimming.

Conclusions

The DW imaging method appears to perform equally or better for the quantification of OEF, despite slightly lower SNR. In clinical practice, adding DW prepared sequences in cardiac MRI protocols may provide more quality black-blood images when irregular ECG-triggering or arrhythmias are present.

References

1. Zheng J, et al. Magn Reson Med 2004;51:718-726.
2. McCommis KS, et al. Magn Reson Imaging 2007;in print.
3. Koktzoglou I, et al, J Cardiovasc Magn Reson. 2007; 9:33-42.
4. Zhang H, et al. J Magn Reson Imaging 2007;26:72-9.
5. Buck A, et al. J Nucl Med 1991;32:1950-1957.