Pitfalls of using T2Weighted Imaging for Visualizing Myocardial Edema using CMR

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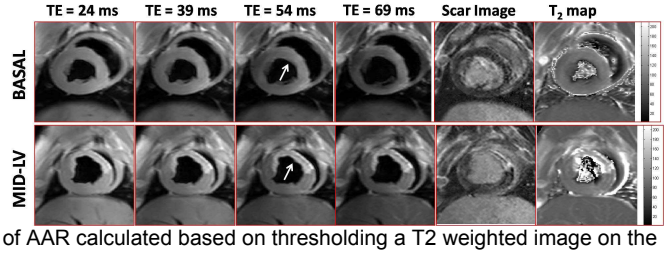
Introduction: Cardiac MR (CMR) is the current clinical gold standard for the assessment of LV function and irreversible myocardial injury. In the setting of acute myocardial infarction, myocardial water content increases by 3-5%, and prolongs the T_2 of the insulted myocardium compared to normal remote myocardium. Several groups have demonstrated that elevated signal intensity in T_2 weighted double-inversion recovery black-blood images can be used as a marker of area at risk (AAR)[1-2]. While a robust assessment of AAR in the immediate aftermath of an acute event, could provide valuable clinical information, there is little consensus in the literature on quantitatively estimating AAR [3]. In this abstract, we attempt to evaluate the potential sources of variability in the estimation of AAR using T2 weighted imaging methods.

Purpose: The purposes of this study are as follows: 1) Estimate the range of T_2 values in normal myocardium and acutely injured myocardium in a pig model; 2) Theoretically assess the effect of the choice of echo time in assessing the AAR; 3) Quantify the extent of AAR in T_2 weighted images at several echo times and T_2 maps using different quantitative metrics.

Methods: All experiments were done on a commercial 3.0T MR scanner (Ingenia, Philips Healthcare) equipped with a 28 channel Torso receive coil, and a dual transmit RF coil capable of performing B_1 shimming [4]. Animal study: Left anterior descending (LAD) artery was occluded (distal to the first diagonal branch) for 45 minutes to induce acute myocardial infarction in five pigs. Within 72 hours following the AMI, the animals were imaged on the MRI scanner. After obtaining localizer images, 3 short axis slices were planned at the basal, mid-cavity, and apical location of the left ventricle. Double inversion black blood fast spin echo images were obtained at these locations at different echo times (TE = 10, 24, 39, 54 and 69 ms) with TR > 3000 ms, and a T_2 map was also obtained from these images. Phase sensitive inversion recovery (PSIR) viability images were also obtained in the same location for determining scar region. Data Analysis: The endocardial and epicardial boundary of the LV in the short-axis orientation, remote myocardium, and the area of injury were manually identified using a custom made program using MATLAB™ (Mathworks, Natick). 1) The AAR was calculated for each of the T_2 *weighted* images at three different threshold levels: AAR was defined as a region whose signal intensity was **mean + 2, 3 and 4 SD** higher than the signal intensity of the remote myocardium. The corresponding T_2 distribution of the areas identified as AAR was also obtained from T_2 maps (as well as the T_2 values of the normal myocardium (not classified as AAR)). 2) The variation of AAR with different T_2 weighting is plotted.

Results: The T_2 value in the region of the injury was on the average 44% longer than the normal remote myocardium. The mean T_2 of the normal myocardium was 92± 10 ms, and for the region of injury was 138 ± 25 ms. There was significant extent of irreversible injury in the LAD territory of the mid-cavity, and apical slices, while there was little or negligible irreversible injury in the basal slice as visualized from viability images. Some representative T_2 weighted images, T_2 map, as well as PSIR images are shown in Figure 1. If the T_2 maps were segmented on the basis of the three thresholds commonly generated based on the mean signal intensity of the normal remote myocardium of the T_2 weighted images, independent of the choice of TE, there was considerable overlap between pixels that are classified as AAR and normal remote myocardium (Figure 2). There was a general trend towards slightly greater separation when thresholds are applied using metrics derived from more heavily T_2 weighted images than in less T_2 weighted images.



Conclusions: The results from the study suggest the following: (i) Following acute injury, there is a broad heterogeneity of T2 values in the region of acute injury, perhaps reflecting the underlying extent of ischemic insult; (ii) Any measure of AAR calculated based on thresholding a T2 weighted image on the basis of the signal intensity of normal myocardium, will have significant overlap with pixels classified as normal based on T2 maps even when the choice of cut-off is 4 SD above the signal intensity of the normal remote myocardium;(iii) There is considerable variation in the signal intensity even within normal myocardium in double inversion recovery black-blood images, and as a result introduce considerable uncertainty in the estimation of AAR. We propose the use of T_2 maps for the estimation of AAR as they are more immune to small signal variations, and are more robust against B_1 field inhomogeneity common to cardiac imaging at high fields (3.0T and above).

References: 1.Cury et al., Circulation 2008, 118:837-844; 2. Eitel,JCMR 2011, 13:13; 3. Viallon et al., JMRI-2011. 4. Krishnamurthy et al., ISMRM proceedings 2011.

Figure 1: Basal and mid-cavity left ventricular T_2 weighted images at various echo times (TE from 24 ms to 69 ms), the corresponding PSIR images, and the T_2 maps are shown for one pig. Note the substantial presence of edema in the mid cavity slice compared to the basal slice.

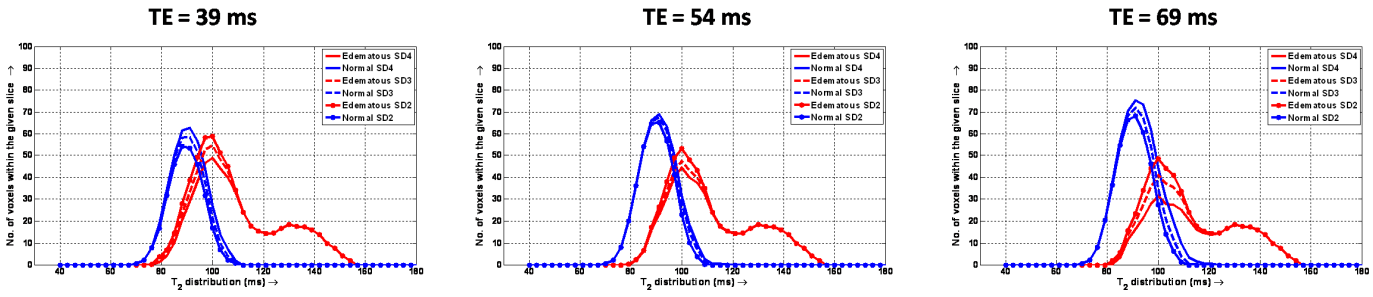


Figure 2: A representative segmentation of the AAR based on various thresholds set based on the signal intensity of normal myocardium on a T2 weighted image shows considerable overlap of T_2 values between AAR and normal remote myocardium. This T2 histogram of the two groups shows substantial overlap at all thresholds evaluated in the study.