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Non-contrast T_1 and T_2 relaxometry characterizes reperfusion injury of acute MI in swine

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Background

Reperfusion injury in acute myocardial infarction (MI) results in edema, necrosis, microvascular obstruction (MVO), and intramyocardial hemorrhage (IMH), the latter presents an interesting clinical target. [1] Cardiovascular MRI has been shown capable of characterizing all of these tissue components. Other than MVO, which is currently detected by flow-deficient regions in contrast enhanced imaging, all other tissue components can be identified by T_1 and T_2 (T_2*). Theoretically, the byproducts of blood breakdown observed with IMH lead to decreased T_1 and T_2 (T_2*). [2] Conversely, free water accumulation (edema) and necrosis lead to increased T_1 and T_2. [2] Hence, direct and quantitative measurement of relaxation rates is promising in myocardial tissue characterization, avoiding ambiguity typical of weighted images (i.e. T_2-weighted spin-echo), undesired signal loss from T_2* (weighted) images or the uncertainty introduced by contrast agent kinetics. *Hypothesis*: Combined T_1 and T_2 mapping can characterize reperfused MI without contrast agents.

Methods

MI was induced in swine by 1 (N=3) or 2 (N=3) hr balloon occlusion of the LAD after the first diagonal, with MRI 7-9 days post MI (Achieva TX, Philips). Relaxometry: 3D respiratory navigator-gated T_2-mapping [3]; 2D Breath-hold T_1-mapping (MOLLI) [4]. Clinical standard: breath-hold black-blood T_2W TSE (BB-T_2-STIR) [5]; early (3 min post) gadolinium-enhanced images (EGE) using PSIR and 0.2 mmol/kg Magnevist. [6]. IMH was identified in T_2W images/T_1/T_2 maps as areas of hypointensity surrounded by hyperintense signal/T_1/T_2 representing edema. MVO was defined in EGE images as hypointense areas surrounded by enhanced MI. The co-localization of tissue types among techniques was examined.

Results

IMH was detected in all animals with 2 hr occlusions, identified by decreased T_1 and T_2, and was spatially consistent with the hypoenhanced core in BB-T_2-STIR and with MVO in EGE. Edema was observed in all animals (elevated $T_1$and T_2). (Fig. 1)

Planimetry showed that relative to remote myocardium, T_1 and T_2 of edema were significantly higher ($p < 0.001$ and $p < 1e-5$, respectively), while within IMH T_1 was lower ($p = 0.001$) and T_2 the same ($p = 0.28$). (Fig. 2)

Conclusions

Though either T_1 or T_2 can be used to separate tissues, combined T_1 and T_2 mapping may allow for more accurate detection of IMH in reperfusion injury, without variability from contrast kinetics, or BB-T_2-STIR artifacts. [7] Based on a small number of animals, T_2 was superior in edema detection, while T_1 performed better in IMH detection. Combined relaxometry may identify tissues with better specificity than individual and may help clarify the link between MVO and IMH. High-resolution relaxometry may be necessary to avoid partial volume.

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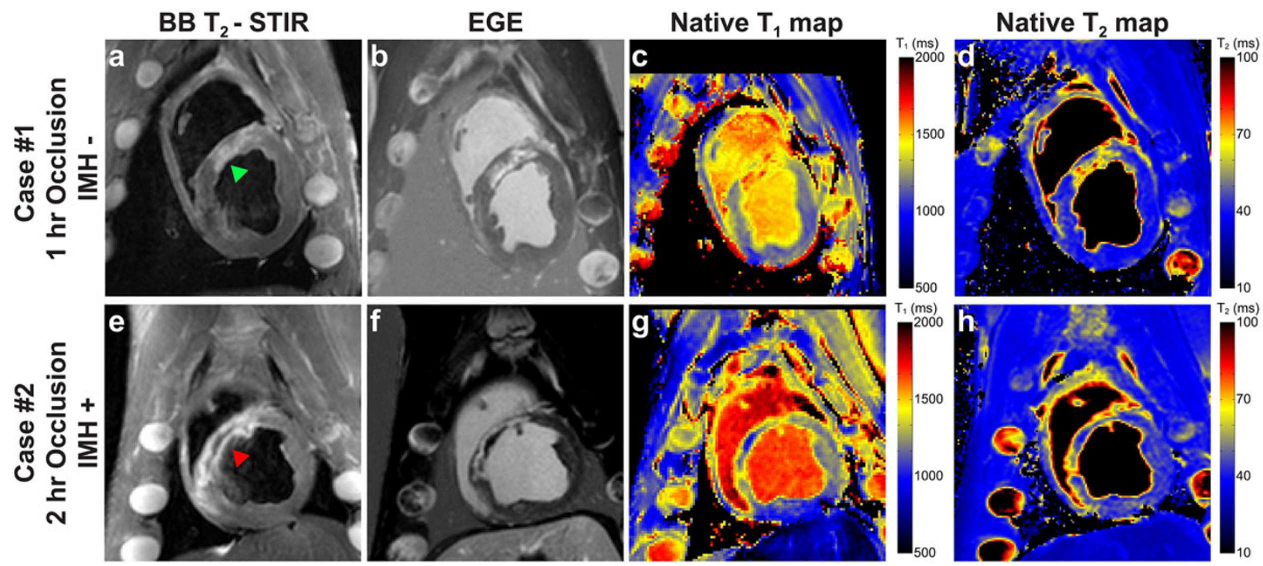

Figure 1 Matched representative SAX images from swine without hemorrhage after 1 hr LAD occlusion (Case #1) (a-d) and with hemorrhage after a 2 hr occlusion (Case #2) (e-h). In Case #1, significant T_1 and T_2 elevation are present in both maps (c,d), though no MVO was observed with EGE (b) nor was a hypointense core present in T_2W images (a). In comparison, Case #2 shows clear IMH, demarked by decrease in T_1 and T_2, surrounded by edema, shown by increased T_1 and T_2 (g and h), all of which are excellently co-localized with that in T_2W (e) and EGE (f). Green arrowhead indicates edema; red arrowhead indicates the core of IMH. Note that T_1 mapping is influenced by off-resonance and lower image resolution. As the result of competing effects on T_1 and T_2 from IMH and edema, partial volume averaging makes the T_2 in IMH close to that of normal myocardium.

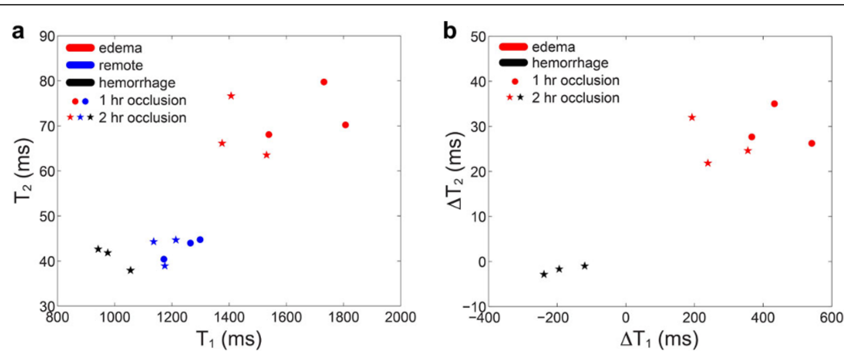

Figure 2 a. ROI-based T_1 & T_2 for edema, IMH and remote myocardium from matched T_1 and T_2 maps. b. Changes in T_1 & T_2 after subtraction of the reference values of remote myocardium. Edema had higher T_2 than both remote myocardium or IMH. T_1 can be used to discriminate between edema, IMH and normal myocardium, though the distributions may overlap. Edema and IMH can be classified with higher specificity using both T_1 and T_2.

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