Time-Evolution of Edema in Reperfused Acute Myocardial Infarction: Implications for Assesment of Area-At-Risk

V. L. Rundell[1], A. Kali[1], X. Zhou[1], Y. Liu[1], R. L. Tang[1], A. Kumar[2], and R. Dharmakumar[1]
[1]Radiology, Northwestern University, Chicago, IL, United States, [2]Laval University

Introduction: Relative edema volume, computed from T2-weighted cardiac MR (CMR) images, has been proposed for the assessment of Area-At-Risk following myocardial infarction and in the determination of salvagable myocardium (1-4). Subsequent to reperfusion, edema presents as hyperintense region on T2-weighted CMR images (2). However, time to imaging and the choice of T2-weighted CMR method may have significant impact on the determination of Area-At-Risk. In this work we investigated the time course and the extent of myocardial edema in reperfused myocardial infarction on the basis of T2-weighted STIR imaging and T2 maps using a canine model subject to ischemia reperfusion (I/R) injury.

Methods: Using CMR, the development and the changes in the persistence of edema volume in the acute post-infarct period was investigated in a canine model using both T_2-weighted STIR imaging and T_2 maps. *Experimental Protocol:* Briefly, LAD instrumented canines (n=9) underwent three hours of reversible no-flow ischemia by inflation of a surgically implanted hydraulic occluder. The absence or presence of blood flow in the subject artery was confirmed by Doppler flow measurement distal to the occlusion point. Following whole heart shimming and scout scans, contiguous, breath-held, ECG-triggered T2-STIR images and T2 maps were acquired in the short-axis orientation at mid diastole to cover the full left ventricle. Images were acquired using a six-channel surface coil on an 1.5T Espree system (Siemens Medical Solutions, Erlangen, Germany) at six time points (before and during ischemia and 2, 5, 7 and 56 days post-reperfusion). Scan parameters for T_2-STIR acquisitions were: TI = 170 ms, TE=64ms, TR=2-3 R-R intervals, resolution=0.9 x 0.9 x 8.0mm^3. T_2 maps were computed from multiple T_2-prepared acquisitions with different preparation times (0, 24, and 55 ms) and bSSFP readout with spatial-resolution of 1.0 x 1.0 x 8.0mm^3 (5). Phase-sensitive Inversion Recovery (PSIR) late gadolinium enhancement images were acquired and used to confirm LAD infarction. *Image Analysis*: Endo- and epi-cardial contours were traced to segment the myocardium and regions of interest (ROI) within the myocardium indicating the presence of edema were determined as follows: For T2 maps the ROI was determined as a region with T_2 values greater than 2SD from remote territories; and for T_2-STIR images the ROI was determined as regions exceeding 2SD of the signal intensity of the remote regions. Edema volume was computed as highlighted (ROI) areas multiplied by imaging slice thickness. Percent volume of edema was computed relative to total myocardial volume.

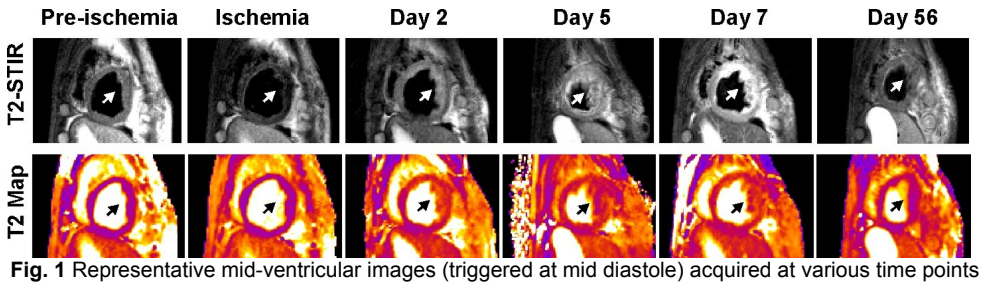

Fig. 1 Representative mid-ventricular images (triggered at mid diastole) acquired at various time points of the ischemia-reperfusion study in a canine. Arrows indicate the LAD territory. Note that the anterior wall demonstrates increased hyperintensity throughout the first seven days post infarction.

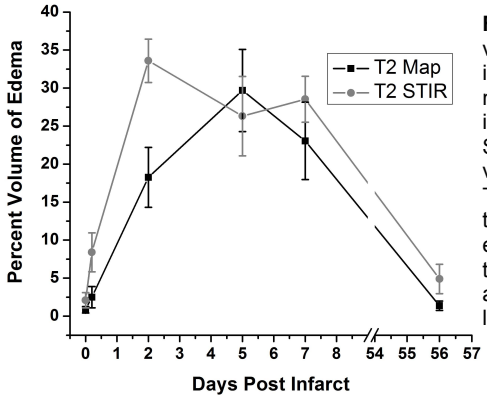

Fig. 2 Time evolution of edema volume in a canine model of ischemia-reperfusion injury measured on the basis of changes in T2 and signal intensity on T2-STIR images: Note that the percent volume of edema measured from T2 maps is generally lower than that from T2 STIR and that the edema volume is variable within the acute period of tissue injury and resolves to near baseline levels by week 8.

Results: Fig. 1 shows a representative set of mid-ventricular images from a canine subject to the ischemia-repefusion study. Fig. 2 illustrates the percent volume of edema (Area-At-Risk) evaluated from offline image analysis. T_2 maps demonstrated a continuous rise in relative edema volume post reperfusion that peaked at day 5. Although edema volume decreased by day 7, it remained significantly elevated from pre-ischemic levels. In T_2-STIR analysis, edema volume rose rapidly, peaking at day 2 and remaining elevated throughout the acute study period. T_2-STIR images showed an earlier peak in edema volume compared to that determined from T_2 maps. Both measures demonstrated regression of edema after 56 days. All data are reported in Table 1.

Conclusion: The finidings from this study indicate that the time following I/R injury, as well as the CMR approach, are critical variables in the determination of Area-at-Risk on the basis of myocardial edema. The implication that Area-at-Risk can be determined on day 2 post-infarct from T2-weighted MR images is likely less reliable in light of these data.

Table 1 Mean percent volume of edema increases in the acute post-infarct period, but return to baseline levels by 8 weeks.

	Pre-ischemia	Ischemia	Day 2	Day 5	Day 7	Day 56
T_2 Maps	0.8±0.4%	2.5±1.4%	18.3±3.9% *	29.7±5.4% *	23.0±5.1% *	1.4±0.6%
T_2 STIR	2.1±1.0%	8.4±2.6%	33.6±2.9% *	26.1±5.2% *	28.5±3.0% *	4.9±1.9%

n = 9 *p<0.01 by ANOVA from pre-infarction percent edema volume. Data reported as mean ± SEM

References: 1. Aletras AH, et al. *Circ* 2006 113:1865-70. 2. Higgins, CB; et al. *Am J Cardiol* 1983 51(1):184-188. 3. Tilak, GS, et al. *Inv Rad* 2008 43(1):7-15. 4. Abdel-Aty, H; et al. Circ 2004 109(20):2411-2416. 5. Giri S JCMR 2009 11:56.