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Native T_1 Mapping by 3-T CMR Imaging for Characterization of Chronic Myocardial Infarctions

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ABSTRACT

OBJECTIVES The purpose of this study was to investigate whether native T_1 maps at 3-T can reliably characterize chronic myocardial infarctions (MIs) in patients with prior ST-segment elevation myocardial infarction (STEMI) or non-ST-segment elevation myocardial infarction (NSTEMI).

BACKGROUND Late gadolinium enhancement (LGE) cardiac magnetic resonance is the gold standard for characterizing chronic MIs, but it is contraindicated in patients with end-stage chronic kidney disease.

METHODS Native T_1 and LGE images were acquired at 3-T in patients with prior STEMI ($n = 13$) and NSTEMI ($n = 12$) at a median of 13.6 years post-MI. Infarct location, size, and transmurality were measured using mean $\pm$ 5 SDs thresholding criterion from LGE images and T_1 maps and compared against one another. Independent reviewers assessed visual conspicuity of MIs on LGE images and T_1 maps.

RESULTS Native T_1 maps and LGE images were not different for measuring infarct size (STEMI: $p = 0.46$; NSTEMI: $p = 0.27$) and transmurality (STEMI: $p = 0.13$; NSTEMI: $p = 0.21$) using thresholding criterion. Using thresholding criterion, good agreement was observed between LGE images and T_1 maps for measuring infarct size (STEMI: bias $= 0.6 \pm 3.1\%$; $R^2 = 0.93$; NSTEMI: bias $= -0.4 \pm 4.4\%$; $R^2 = 0.85$) and transmurality (STEMI: bias $= 2.0 \pm 4.2\%$; $R^2 = 0.89$; NSTEMI: bias $= -2.7 \pm 7.9\%$; $R^2 = 0.68$). Sensitivity and specificity of T_1 maps for detecting chronic MIs based on thresholding criterion were 89% and 98%, respectively (STEMI), and 87% and 95%, respectively (NSTEMI). Relative to LGE images, the mean visual conspicuity score for detecting chronic MIs was significantly lower for T_1 maps ($p < 0.001$ for both cases). Median infarct-to-remote myocardium contrast-to-noise ratio was 2.5-fold higher for LGE images relative to T_1 maps ($p < 0.001$). Sensitivity and specificity of T_1 maps for visual detection were 60% and 86%, respectively (STEMI), and 64% and 91% (NSTEMI), respectively.

CONCLUSIONS Chronic MIs in STEMI and NSTEMI patients can be reliably characterized using threshold-based detection on native T_1 maps at 3-T. Visual detection of chronic MIs on native T_1 maps in both patient populations has high specificity, but modest sensitivity. (J Am Coll Cardiol Img 2015;8:1019–30) © 2015 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

AHA = American Heart Association

CI = confidence interval

CMR = cardiac magnetic resonance

CNR = contrast-to-noise ratio

LGE = late gadolinium enhancement

MI = myocardial infarction

IQR = interquartile range

MOLLI = modified Look-Locker inversion recovery

NSTEMI = non-ST-segment elevation myocardial infarction

SI = signal intensity

STEMI = ST-segment elevation myocardial infarction

Determining infarct location, size, and transmurality can be instrumental in the clinical management of patients with prior myocardial infarction (MI) (1,2). In patients with prior MI, the risk of sudden cardiac death (3) or major adverse complications, such as heart failure (1), have been directly related to chronic MI characteristics (infarct size, location, and transmurality). Visualization and quantification of MI by late gadolinium enhancement (LGE) cardiac magnetic resonance (CMR) has been vital to building this understanding (4,5). Several studies now support the belief that LGE CMR can be helpful in identifying chronic MI patients for implantable cardiac defibrillators for primary prevention of sudden cardiac death (6).

In spite of its capabilities, a well-known limitation of LGE CMR is the requirement for gadolinium-based contrast agents, which are contraindicated in patients with severe kidney dysfunction (7–9). In fact, given the comorbidity of late-stage renal failure in patients with ischemic heart disease (10,11), LGE CMR is estimated to be contraindicated in nearly 20% of MI patients. Hence, a CMR approach that could visually detect and quantify chronic MI without exogenous contrast media would be immensely valuable in the overall diagnosis and management of MI patients.

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Using a canine model of reperfused chronic MI, we previously demonstrated that native T_1 mapping at 3-T provides significantly greater sensitivity and specificity for characterizing chronic MI over native T_1 mapping at 1.5-T (12). In this study, we examined whether native T_1 mapping at 3-T can be clinically useful in the characterization of chronic MI in patients with a prior history of healed ST-segment elevation myocardial infarction (STEMI) or non-ST-segment elevation myocardial infarction (NSTEMI) relative to LGE imaging.

METHODS

CMR STUDIES. Patients (13 STEMI and 12 NSTEMI) with prior MI were studied according to the protocols approved by the Institutional Review Board of Severance Hospital, Yonsei University Health System, at a median of 13.6 years (interquartile range [IQR]: 7.5 to 18.5 years) after acute MI. CMR studies were performed on a 3-T clinical magnetic resonance system (MAGNETOM Trio, Siemens Healthcare, Erlangen, Germany) after obtaining informed consent. Patients were excluded from the study if they had symptoms of chest pain, electrocardiogram changes, or cardiac enzyme elevation within 1 year before the date of CMR examination; multiple infarctions; or were contraindicated in a magnetic resonance study (claustrophobia, metallic implants, glomerular filtration rate <45 ml/min/1.73 m^2, and so on). The patients' clinical features are summarized in **Table 1**. Electrocardiogram-triggered breath-held 2-dimensional cine balanced steady-state free precession (25 to 30 cardiac phases, repetition time/echo time = 2.92/1.46 ms, flip angle = 50°, bandwidth = 888 Hz/pixel, voxel size = 1.3 × 1.3 × 8 mm^3), pre-contrast modified Look-Locker inversion recovery (MOLLI) (8 inversion times [TI] with 2 Look-Locker cycles of 3 + 5 images [13]; Siemens Works in Progress Package number 448, minimum TI = 120 ms, TI increment = 80 ms, flip angle = 35°, bandwidth = 1,085 Hz/pixel, voxel size = 1.5 × 1.5 × 8 mm^3), and LGE images (inversion recovery prepared segmented fast low-angle shot, acquired 10 to 12 min following intravenous administration of 0.2 mmol/kg of gadobutrol [Gadovist, Bayer Schering Pharma, Berlin, Germany]; and optimal TI for nulling the remote myocardium; repetition time/echo time = 6.54/3.27 ms; flip angle = 20°; bandwidth = 460 Hz/pixel; voxel size = 1.2 × 1.2 × 8 mm^3) were acquired along the short-axis direction covering the entire left ventricle.

IMAGE ANALYSIS. Motion-corrected native T_1 maps were constructed from the nonrigid motion-corrected pre-contrast MOLLI images as previously described (14) by the scanner's image reconstruction system. All image analyses were performed on cvi42 (Circle Cardiovascular Imaging Inc., Calgary, Canada). LGE images and T_1 maps were randomized and independently analyzed by 2 blinded reviewers in consensus. The locations of remote myocardium on both techniques were identified as the regions showing no hyperintensity on the respective images and reference regions of interest were drawn in the remote

(PCT/US14/53938) on the use of T_1 mapping at 3-T for characterizing chronic myocardial infarction. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose. Drs. Kali and E.-Y. Choi contributed equally to this work.

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