Detecting Right Ventricular Involvement in Reperfused Myocardial Infarction with T2-weighted Cardiac MR and IR-prepared SSFP with Delayed Contrast Enhancement

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Introduction: Right ventricular (RV) myocardial infarction and dysfunction are independent indicators of poor prognosis in patients with acute myocardial infarction (AMI) (1,2). Conventional delayed enhancement magnetic resonance imaging (DE-MRI) using inversion-recovery fast gradient-echo (IR-FGRE) has been used to detect the RV involvement in AMI, but its sensitivity and specificity is limited by the thinned wall and confounded by the pericardial fat tissue. T2-weighted cardiovascular MR (CMR) is a validated and accurate method to detect the presence and extent of myocardial edema (3), which is an early manifestation of myocardial injury during the evolution of AMI. A newly developed DE-MRI technique based on IR prepared steady-state free precession (SSFP) has been proposed for the simultaneous detection of scar tissue and wall motion abnormalities in patients with chronic MI (4). We hypothesize that a T2-weighted CMR technique with fat saturation is a better method to identify RV involvement in the acute stage of reperfused MI, and that the DE-MRI technique based on IR prepared SSFP is a better technique to demonstrate the RV involvement in the chronic stage of reperfused MI.

Materials and Methods: In seven Yorkshire pigs (22-30 kg) a reperfused MI was produced by a 90-minute percutaneous balloon occlusion of the left anterior descending coronary artery (LAD) proximal to the right ventricular branch. After reperfusion and full recovery from anesthesia, animals were allowed to survive for six weeks (n=7).

MR studies were conducted on a GE 1.5T Signa Excite system and included two examinations: the first was done in the acute phase of reperfused MI at one-week and the second was conducted in the chronic phase of reperfused MI at six weeks. Both MR examinations included an SSFP functional study and conventional IR-FGRE based DE-MRI. The MRI examination at one-week included a T2 weighted double IR pulse sequence pre-contrast and the follow-up MRI at six-weeks included an IR-prepared SSFP based DE-MRI post-contrast. The double IR technique, a black blood method which applies magnetization preparation with two consecutive 180 degree pulses to achieve the blood suppression, was used for the T2 weighted imaging. The addition of third pulse was used to achieve fat saturation. The double IR pulse sequence (TR=2 R-R intervals, TE~68 ms) was applied before Gd-DTPA injection in most animals. In one animal, the double IR was applied both pre-contrast and post-contrast. DE-MRI was performed 15-20 minutes after a double-dose bolus injection of Gd-DTPA. For IR-FGRE, TI varied from 150 to 300 ms, depending on the null of normal myocardium. For IR-SSFP, the SSFP is applied during IR, which means that the longitudinal magnetization is sampled during the transition process of T1 recovery toward steady-state (4). For the double IR, IR-FGRE and IR-SSFP based DE-MR, the in-plane resolution was around 1mm*1mm. Short-axis oblique slices (slice thickness of 5 mm without gaps) covering the entire left ventricle (LV) were acquired using all MRI pulse sequences. Axial transverse slices were selectively obtained to better demonstrate the RV abnormalities. Upon the completion of MRI examinations all animals were sacrificed for macroscopic examination, TTC staining and/or histology for the verification of reperfused MI in LV and the RV involvement.

Results: Macroscopic examination of the excised heart, TTC staining, and/or histology confirmed the presence of LV-MI and the RV involvement in all animals. The gross appearance of chronic MI was gray-white scarring in both LV and RV with increased collagen deposition in histology. In TTC staining, regions of myocardial necrosis were indicated by failure to stain, appearing as a pale-white area in contrast to red-stained viable myocardium.

For the detection of LV-MI, double IR with fat-saturation acquired in the acute phase yielded results similar to the IR-FGRE based DE-MRI technique which identified the presence and extension of LV-MI both in acute and chronic stages in all animals. In two animals, a hypo-intense core (most likely hemorrhagic tissue) surrounded by a hyper-intense region (edematous and necrotic tissue) was noted in double IR T2 weighted images. In the identification of LV-MI in the chronic phase, IR-SSFP based DE-MRI method demonstrated a much better image quality compared to IR-FGRE based DE-MRI technique; this is primarily attributed to the multiple imaging contrasts provided by IR-SSFP.

For the detection of RV involvement (Figure 1), IR-FGRE based DE-MRI was ineffective, with a detection rate of 14.3% (1/7) in both acute and chronic stages of MI. In contrast, the T2 weighted double IR technique with fat-saturation successfully demonstrated the limited but evenly distributed region of high signal intensity in the RV anterior wall in six of seven animals (85.7%), which represented the signal mixture from myocardial edema and necrosis in the early stage of MI. In chronic MI, the demonstration of RV involvement on short-axis oblique and axial transverse slices was much better using IR-SSFP (85.7%, 6/7) compared to IR-FGRE. The presence of pericardial fat tissue and the thinned wall of the RV were the primary culprits for poor identification of RV involvement using IR-FGRE. The multiple-contrast capability using IR-SSFP enabled better differentiation between the blood pool, pericardial fat and the delayed hyper-enhanced region of RV involvement, in which the combined RV- and LV-MI appeared as the characteristic MR sign of a transverse or inverted "Y" shape (Figure 1). Moreover, the IR-SSFP provided cine images that also enabled the better appreciation of RV wall motion abnormalities in the region of MI.

Conclusions: For the identification of RV involvement in reperfused MI, a T2 weighted double IR method with fat-saturation is a sensitive technique in acute MI and IR-prepared SSFP based DE-MRI is a better technique in the chronic phase, compared to conventional IR-FGRE based DE-MRI. Further clinical investigation is warranted to establish the true utility of these techniques in the identification of RV myocardial infarction.

References: 1. Assali AR, et al. Am Heart J 2007; 153: 231-237. 2. Larose E, et al. J Am Coll Cardiol 2007; 49: 855-862. 3. Adel-Aty H, et al. JMRI 2007; 26: 452-459. 4. Detsky JS, et al. MRM 2007; 58: 365-372.

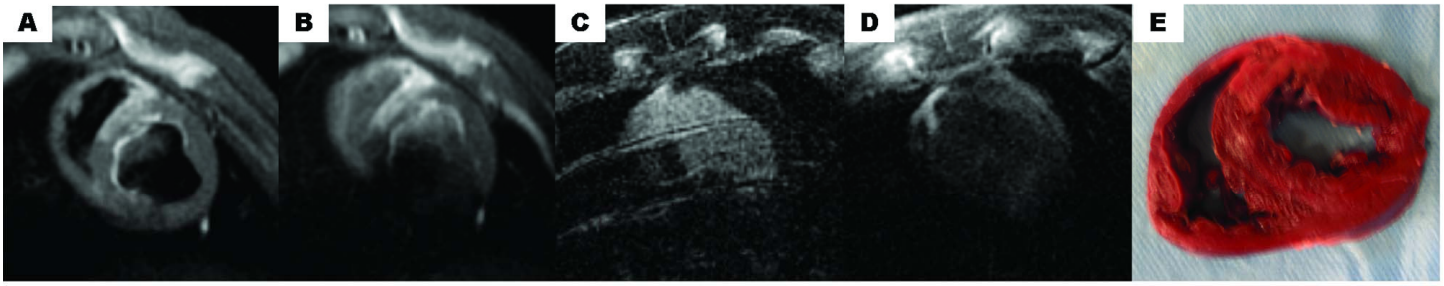

Figure 1. RV involvement in a porcine model with reperfused MI at one week (Fig.1A and 1B) and at six weeks (Fig.1C and Fig.1D). Short-axis oblique DIR T2W images pre-contrast (A) and post-contrast (B): high signal intensity noted in the regions of RV- and LV-MI; C. Axial IR-FGRE based DE-MRI: RV-MI was barely visualized, LV-MI was seen as delayed hyper-enhancement in the anterior septal region of LV; D. axial IR-SSFP based DE-MRI (same location as C): RV-MI and LV-MI was much better demonstrated as a characteristic sign of inverted "Y"; E. TTC staining confirmed the presence of RV involvement.