DTI Study of Postinfarct Myocardium Structural Remodeling in Porcine Model

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Introduction

Structural investigation of infarcted heart can lead to better understanding of the heart functional adaptation and remodeling process. Only few MRI studies have been reported so far. Chen J *et al* [1] investigated the infarct region in rat heart in vitro with diffusion tensor imaging (DTI) and found increased trace ADC, decreased fractional anisotropy (FA) and spread of local helix angles associated with the disarray and loss of myocardial fibers. Recently Wu M e*t al* [2] studied trace ADC, FA and fiber architecture in correlation with infarct size and left ventricular function in patients with acute myocardial infarction, and reported similar findings in the infarct region and ADC increase in region adjacent to infarction. However, a through study of such postinfarct structural remodeling in well-controlled animal model with comprehensive DTI analysis is needed. In this study, CMR and DTI were employed to study the function in vivo and structural abnormality ex vivo in porcine model of myocardial infarction.

Method

MRI experiments were conducted on a 3T Philips Achieva MR imager and porcine model of infarction was created using LAD ligation with infarct located in the septum wall near the apex (infarct N=6; control N=6). 14 weeks later, all pigs were studied with MRI. (a) CMR study: ECG-trigger breath-hold balanced-FFE was used to obtain cine images of 8 slices covering whole heart. The parameters were: TR/TE=5.5/2.2ms, slice thickness=8mm, cardiac frames=20, flip angle=45º and in-plane resolution=1.04×1.04mm^2. Delayed enhanced T1-weighted images were obtained ten minutes after Gd injection at a dose of 0.1 mmol/kg. TR/TE=3.8/1.3ms, TI=275ms, flip angle=15º. (b) DTI study: All animals were sacrificed after CMR study and the excised heart samples were suspended in a cylinder filled with formalin. DTI was performed along the short-axis of left ventricle using spin echo EPI (SE-EPI). Imaging parameters were: TE=45ms; TR=4.0s; slice gap=0 mm; diffusion b=800 s/mm^2; number of gradient directions=15; number of slices=~40; and NEX=40 with isotropic resolution of 1.13mm^3. The total scan time for each heart sample was ~50 min. The image co-registration was first performed. DTI parameters were then calculated and exported to a software toolkit developed in MATLAB for further processing. LV myocardial papillary muscles and RV were excluded in the analysis. Four slices that covered the infarction were chosen for analysis. For each slice, infarcted myocardium was identified and 2D angle (infarct angle) covering infarction was measured. Remaing myocardium was divided into 6 radial segments with equal angles. The 2 segments adjacent to infarct region were classified as region adjacent to infarct, and the remaining 4 segments were remote region (Fig.1). For control, a quarter of the slice was regarded as sham infarct region, and sham adjacent and remote regions were obtained using the same segmentation method as applied in infarct group for comparison. Ejection fraction (EF) and LV wall shortening was measured from cine images and infarct volume was obtained from delay enhancemnet images. FA, trace ADC, three major eigenvalues (λ_1, λ_2 and λ_3) and fiber orientation were measured from DTI data. Because infarcted region was thin, LV wall shortening and standard deviation (SD) of fiber helix and transverse angles were computed only at adjacent and remote reigons. Correlational analysis between infarction size, cardiac functions and DTI parameters in 3 regions were performed.

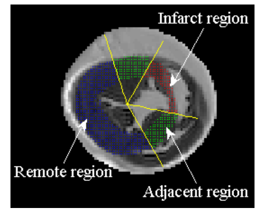

Fig.1 Region definitions

Results

EF decrease correlated with infarct volume increase (R=0.93, not shown). For each slice that covered infarction, LV wall shortening was found to decrease with infarct angle increase (R=0.66 in adjacent region and R=0.82 in remote region). FA showed negative correlation with infarct angle, especially in infarct region (Fig.2). Trace ADC increased in infarct region (R=0.77) but remained largely unchanged in adjacent and remote regions with increase of infarct angle (R=0.14 and R=0.39 in adjacent and remote region, respectively). Similar results were found on three major eigenvalues. Significant FA difference was found in infarct region between infarct and control group using unpaired student's t-test (p<0.05); and infarct region was significantly different from the other two regions in infarct group based on paired student's t-test (p<0.05), including adjacent vs. remote regions (Fig.3). In addition, standard deviation (SD) of fiber helix and transverse angles illustrated positive correlation with infarct angle (Fig.4), and it was usually greater in adjacent than that of remote region (p<0.05 using paired student's t-test, not shown).

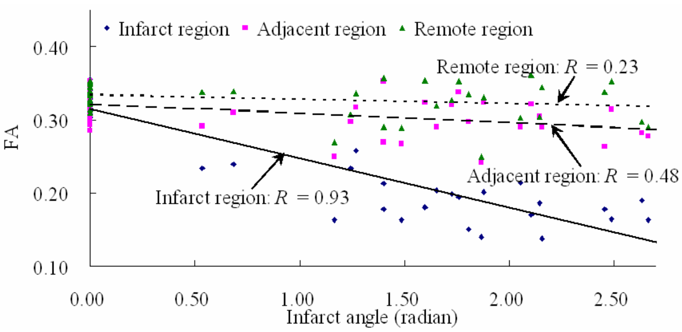

Fig.2 FA varied with infarct angle in three regions

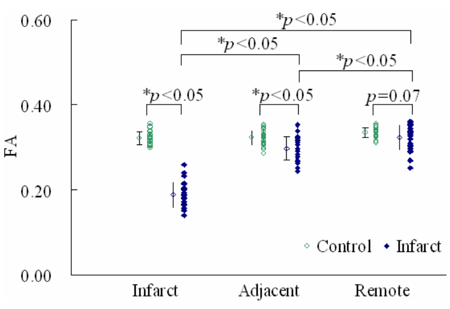

Fig.3 FA values in three regions

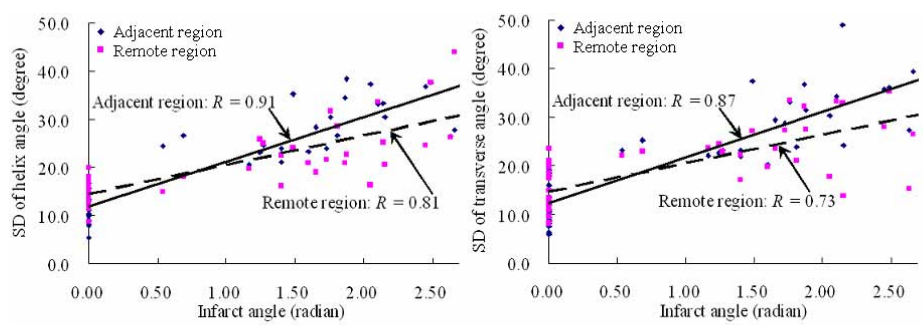

Fig.4 Standard deviation (SD) of helix and transverse angles varied with infarct angle

Discussion

Remodeling of infarct myocardium in porcine was examined by CMR and DTI 14 weeks after LAD ligation. EF, wall shortening and FA showed negative correlation with infarct angle. Trace ADC and three major eigenvalues in infarct region increased with infarct angle, but remained largely unchanged in both adjacent and remote regions. SD of both helix and transverse angles in adjacent region was significantly higher than that in remote region. Increase of such angular deviations was also found to correlate with infarct angle. These results indicated that postinfarct structural remodeling involves both local and surrounding myocardium in terms of myocardial fiber structural degradation, and that cardiac DTI has the potential to reveal and assess these subtle processes together with functional CMR measurements.

References

[1] Chen J *et al*, Am J Physiol Heart Circ Physiol, vol. 285: H946-H954, 2003

[2] Wu M *et al*, Circulation, vol. 114: 1036-1045, 2006