MR diffusion tensor investigation of transmural heterogeneity of myocardium structural remodeling in postinfarct porcine model

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Introduction

It was reported that alteration of cardiac function and viability of infarcted heart varies transmurally [1, 2], which may relate to the structural remodeling of the respective myocardial layers. Recently, diffusion tensor imaging (DTI) technique has emerged as a powerful tool to nondestructively evaluate tissue structure with high spatial resolution. However, previous DTI studies of infarcted hearts predominantly focused on the overall myocardial diffusion changes within a certain region [3-5] and neglected the possibility of transmural heterogeneity in the structural degradation. In this study, we explored the variation in transmural myocardium remodeling to provide complementary information and reveal the underlying mechanisms of altered cardiac performance in infarct state.

Method

Imaging experiments were conducted on a 3T Philips Achieva MR imager. Six porcine was induced infarction at septum near apex with LAD ligation. 13 weeks later, the infarcted animals with controls (N=6) were sacrificed and the excised hearts were fixed with formalin. DTI was performed along the short-axis of LV using SE-EPI with the following parameters: TE=45 ms; TR=4.0 s; slice gap=0 mm; diffusion b=800 s/mm^2; 15 gradient directions; number of slices=~40; and NEX=40 with isotropic resolution of 1.13 mm^3. The scan time was ~50 min per sample. Ten slices covering infarction were chosen with infarct regions identified as hyperintense in B_0 images. Bilateral segments of infarct region with 1/4 length of infarction were defined as adjacent region, and the remaining part was defined as the remote region [5]. For the controls, a quarter of each slice with center located at septum was regarded as sham infarct region, with sham adjacent and sham remote regions subsequently defined (Fig.1). Myocardium wall of the adjacent or remote region was equally divided into five zones labeled as Z1 to Z5 from epicardium to endocardium. Fractional anisotropy (FA), mean apparent diffusion coefficient (MD), axial diffusivity ($\lambda_{//}$) and radial diffusivity ($\lambda_{\perp}$) were calculated at each transmural zones. Student's t-test was applied to exam the difference between infarct and control groups with $p<0.05$ regarded as statistical significance.

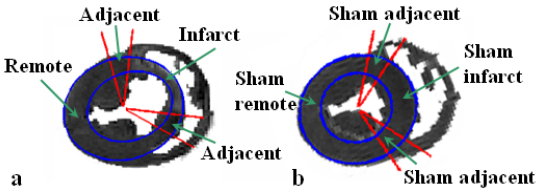

Fig. 1 Region definition.

Results

Comparisons of FA, MD, $\lambda_{//}$ and $\lambda_{\perp}$ between infarct and control groups were shown in Fig. 2. No significant change of FA was observed at all transmural zones at the both adjacent and remote regions, indicating that no severe deterioration of fiber organization or integrity occurred in the non-infarcted myocardium. However, values of MD and $\lambda_{\perp}$ at the adjacent region were found to decrease significantly at the transmural zone of Z5, and $\lambda_{//}$ reduced substantially at Z4 and Z5 in infarct group. Similarly, at the remote region, MD and $\lambda_{\perp}$ were found to be significantly lower at Z4 and Z5, and $\lambda_{//}$ conspicuously smaller at Z3 to Z5 in infarct group than those of controls. These findings suggest that the diffusivity change in infarcted heart typically occurred around endocardium earlier than epicardium. Averaged values of DTI indices were measured within the entire adjacent and remote regions, but no apparent difference was found between infarct and control groups (not shown).

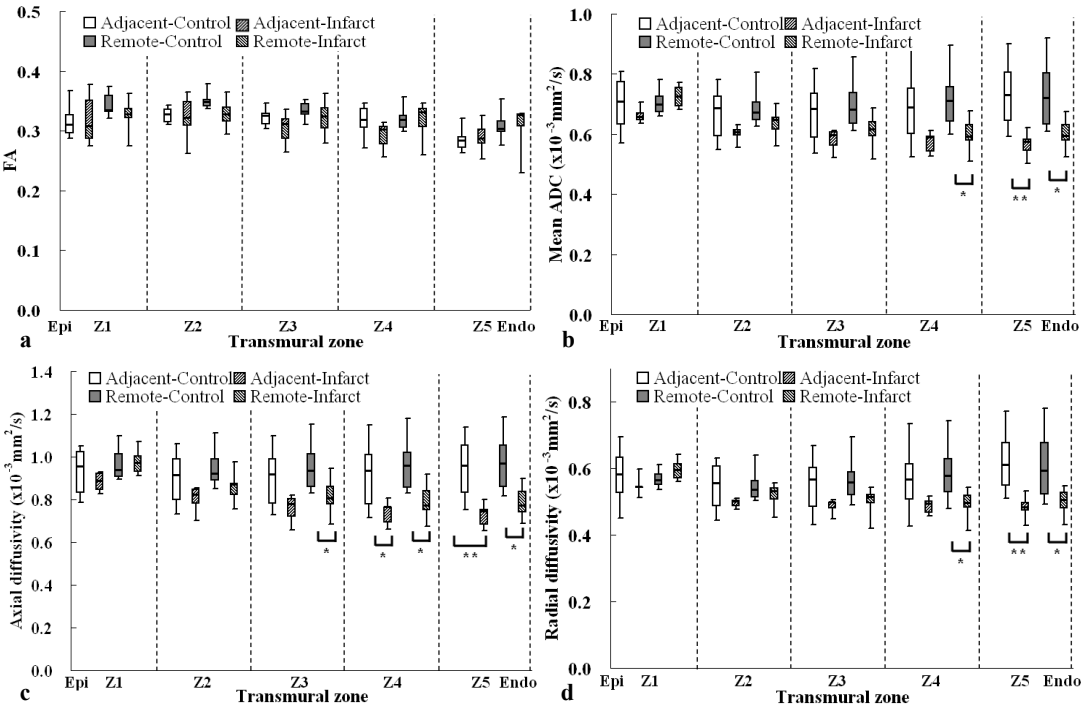

Fig. 2 Box plot of FA (a), MD (b), $\lambda_{//}$ (c) and $\lambda_{\perp}$ (d) at five transmural zones. *p<0.05 and **p<0.01.

Discussion

Significant reduction of diffusivities, including MD, $\lambda_{//}$ and $\lambda_{\perp}$, was observed to occur earlier around endocardium at both adjacent and remote regions. The experimental DTI results suggest that myocardium structural remodeling is transmurally heterogeneous and that the endocardium is more sensitive to infarct injury, which is general agreement with the studies of the myocyte fibrosis and necrosis in infarcted hearts by other histological methods [2, 6]. The decrease of diffusivities was likely related with the shrinkage of myocardial fiber, as loss of myocyte predominated over the hypertrophy of the viable myocardium in infarcted heart [7-8]. Functionally, greater strains were reported to preserve in fibers at endocardium than at other transmural layers [9]. Therefore, the significant structural degradation at endocardium would affect the performance of fibers there, which eventually led to substantial functional degradation. Altogether, our experimental findings not only suggest the necessity of examining transmural variation of myocardium structural remodeling in infarcted heart, but also demonstrate DTI is a sensitive tool to reveal the subtle structural change at cellular level.

References

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