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Diffusion tensor shape measurements of infarcted myocardium in porcine models using three phase geometric analysis

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Introduction

Diffusion tensor imaging (DTI) has emerged as a powerful tool for rapid measurement of myocardium fiber structure and geometry with high spatial resolution nondestructively. Several DTI studies were conducted to investigate infarcted left ventricular (LV) myocardium structure with focusing on diffusion anisotropy and diffusivities, such as fraction anisotropy (FA) and apparent diffusion coefficient [1-4], from which, however, little tensor shape information of infarcted myocardium could be provided. Recently, parameters of CL, CP and CS were proposed to describe linear, planar and spherical anisotropies, respectively [5]. These parameters representing the shape of the diffusion tensor with a combination of linear, planar and spherical measures are known to be related with tissue structures [5]. In current study, DTI was performed in infarcted porcine models with tensor shape examined and illustrated on a three-phase (3P) space [5]. The diffusion tensor shape of infarcted myocardium was investigated for the first time and the supplemental information of LV myocardium structural remodeling was provided.

Method

Imaging experiments were conducted on a 3T Philips Achieva MR imager. LAD and LCX ligation were performed to create infarctions at septum near apex and lateral wall around base with denoted as infarct #1 and infarct #2, respectively ($N=6$ for control and each infarct group). 13 weeks after ligation, all animals were sacrificed and the excised hearts were fixed with formalin. DTI was performed along the short-axis of LV using SE-EPI with following parameters: TE=45ms; TR=4.0s; slice gap=0 mm; diffusion b=800 s/mm²; 15 gradient directions; number of slices~40; and NEX=40 with isotropic resolution of 1.13mm³. The scan time was ~50 min per sample. Ten slices covering infarction were chosen with infarct regions identified as hyperintense in the T2-weighted images (i.e., DWIs with b value = 0), typically exhibiting thin myocardium wall [4]. Remaining myocardium was equally divided into 6 radial segments. The 2 segments adjacent to infarct region were classified as adjacent region, and the remaining 4 segments were remote region (Fig.1). For control, a quarter of the slice with center at similar location as corresponding infarct group was arbitrarily regarded as sham infarct region, and sham adjacent and remote regions were subsequently defined [4]. Three eigenvalues were obtained from DtiStudio, from which FA, CL, CP and CS were calculated [5]. Bivariate normal distribution of tensor shape measurements were estimated from the selected data. Isocontours of one standard deviation from the mean location in 3P space were plotted using a barycentric coordinate system with isocontours of FA at 0.2, 0.4, 0.6 and 0.8 indicated. Values of FA, CL, CP, and CS of infarct and control groups were compared and student's t-test was applied with $p<0.05$ regarded as significance.

Results

In infarct region, the tensor shape isocontours of infarct and control groups separated obviously (Fig. 2a), implying substantial structural alteration of infarcted myocardium. The isocontours of the two infarct groups overlapped each other and clustered near the top of the 3P space, indicating that the two infarct groups have similarly higher isotropic diffusion properties than controls. The isocontours of the two control groups overlapped each other and located in the regions with more anisotropic property and larger FA values than that of infarct groups. In adjacent and remote regions, the isocontours of infarct and control groups overlapped each other (Fig. 2b-c), and this unapparent difference of tensor shape may suggest that no severe structural remodeling occurred in these two regions. For both of the two infarct groups, FA, CL and CP decreased substantially, but CS increased significantly in infarct region (Fig.3a). In adjacent region, significant decrease of CL in infarct #1 was found with no obvious change of FA. Significant increase of CS was obtained in infarct #2 with significant decrease of FA (Fig. 3b). In remote region, no substantial alteration was found in infarct #1, but significant change of CP and CS was found in infarct #2 with no apparent change of FA (Fig. 3c). These results indicate that the structural remodeling of infarcted myocardium in adjacent and remote regions involved change of CL, CP and CS, which appear to be more sensitive to subtle change of diffusion anisotropies than the conventionally used FA. No significant difference of the tensor shape was exhibited between the two infarct groups in all three regions, suggesting that the change of tensor shape was independent of infarct locations.

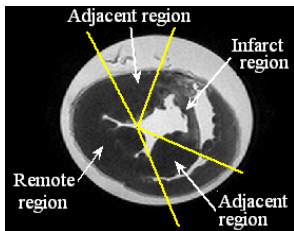


Fig.1 Region definitions.

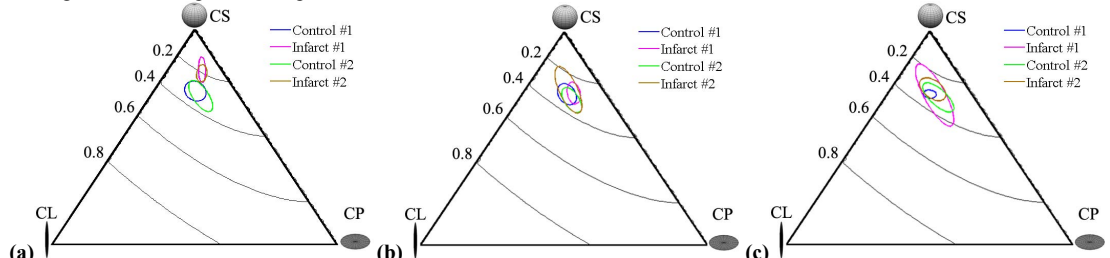


Fig.2 Isocontours of diffusion tensor shape in infarct (a), adjacent (b) and remote (c) regions on 3P space.

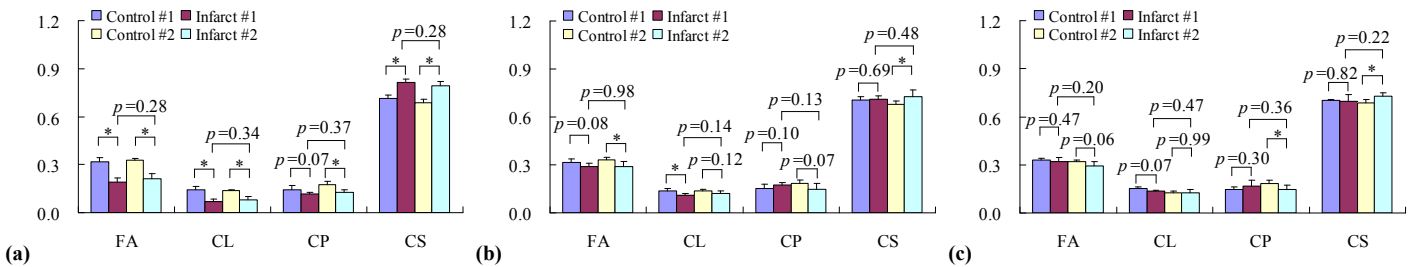


Fig.3 Comparisons of FA, CL, CP and CS between infarct groups and their corresponding controls in infarct (a), adjacent (b) and remote (c) regions. * $p<0.05$.

Discussion

In current study, two groups of porcine models with different myocardium infarct locations were created and diffusion tensor shape was investigated using DTI. In infarct region, the tensor shape of infarct groups is more isotropic with significantly lower CL and CP and higher CS than corresponding controls. These highly isotropic diffusion properties may be associated with myocardial fiber swelling and tearing as reported in [1, 4]. Substantial decrease of CL, CP or increase of CS was exhibited in adjacent and remote regions while FA has no apparent change, suggesting the three measurements of tensor shape are more sensitive to detect subtle change of diffusion properties than conventionally used parameter. No significant difference was observed between the two infarct groups, implying the neglectable influence of infarct location on myocardium structural degradation. Such characterization of diffusion tensor shape using DTI gives insights into myocardial fiber morphological alteration and demonstrates its potential application in detecting structural remodeling of diseased hearts.

References

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