Investigation of myocardium structure of postinfarct porcine model using superquadric glyphs

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Introduction

Diffusion tensor imaging (DTI) has been demonstrated to be a powerful tool for assessment of myocardium at high spatial resolution. Several DTI studies were conducted to investigate infarcted left ventricular (LV) myocardium structure with focusing on myocardial fiber orientation, diffusivity or diffusion anisotropies [1-4]. However, more information remains to be elucidated, including diffusion tensor shape and myocardium laminar sheet structure which plays a major role in cardiac deformation and electrical activation propagation [5]. Recently, superquadric glyphs have been proved to be superior to facilitate the visualization of spatially varying tensor data than conventionally used ellipsoids [6]. In current study, superquadric glyphs were applied on infarcted porcine model. Diffusion tensor shape and laminar sheet structure of infarcted LV myocardium were examined for the first time to provide informative and intuitive description of myocardium structural alteration.

Method

Imaging experiments were conducted on a 3T Philips Achieva MR imager. LAD ligation was performed on porcine models (N=6) to induce infarction at septum near apex. Thirteen 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 following parameters: TE=45ms; TR=4.0s; slice gap=0mm; diffusion b=800s/mm^2; 15 gradient directions; number of slices=~40; and NEX=40 with isotropic resolution of 1.13mm^3. The scan time was ~50 min per sample. DTI data was imported into MedINRIA for processing. Ten slices covering infarction were chosen with infarct regions identified as hyperintense in B_0 images, typically exhibiting thin myocardium wall [3]. Remaing 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. For control, a quarter of the slice with center at septum was arbitratily regarded as sham infarct region, and sham adjacent and remote regions were subsequently defined [3]. Linear anisotropy (Cl), planar anisotropy (Cp) and spherical anisotropy (Cs) were calculated at three regions [6]. Myocardium at adjacent and remote regions were selected (Fig.1) and the laminar sheet structure was visualized with superquadric glyphs and ellipsoids, respectively. The images were colored with the direction of the primary eigenvector (red - left and right, green - anterior and posterior, and blue - inferior and superior). Student's t-test was applied with p<0.05 regarded as significance.

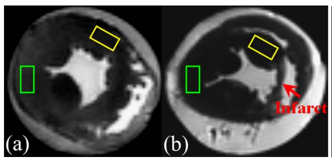

Fig.1 Control (a) and infarct (b) hearts with adjacent (yellow) and remote (green) regions selected.

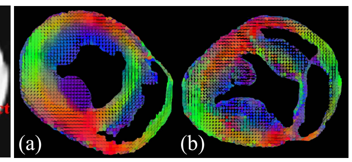

Fig.2 Superquadric glyphs maps of control (a) and infarct (b) hearts.

Results

Superquadric glyphs maps of slices selected from control and infarcted heart were shown in Fig.2. Clear double-helical structure was seen in control heart with fibers running circumferentially in midwall and longitudinally in epicardium and endocardium. However, in infarcted heart, such structure appeared to be totally lost in infarct region and became contaminated in adjacent region by infarction, suggesting fiber orientation altered not only in the infarcted but also in the surrounding non-infarcted regions. Fig. 3 compares Cl, Cp and Cs between infarct and control groups. For infarct group, significant decrease of Cl was found in both infarct and adjacent regions. Substantial increase of Cs was only observed in infarct region. No apparent change of Cp was found in all three regions. The results may indicate that change of tensor shape was mainly involved the alterations of Cl and Cs in infarct and adjacent regions. Fig.4 illustrates the myocardium laminar sheet structure in adjacent regions. Well-organized sheet structure could be more easily observed using superquadric glyphs (Fig.4a) than using ellipsoids (Fig.4b) in control heart. However, the laminar sheet structure in infarcted heart was difficult to be traced with less organized fiber orientation (Fig.4c and 4d). Although ellipsoids could describe the tensor shape and fiber orientation to some extent, it was limited in depicting laminar sheet structure as it provided no information of how various tensor components relate to one another within a voxel or between neighbors (Fig.4b and 4d). In remote region, obvious laminar sheet structure was seen in both control and infarct hearts with using superquadric glyphs (Fig.5a and 5c). However, the laminar sheet structure of infarct heart seemed to change with circumferentially-orientated fibers tilting more longitudinally compared to that of control heart, suggesting alterations of laminar sheet structure occurred in remote region. The laminar sheet structure was hardly observed by using ellipsoids in remote region (Fig.5b and 5d).

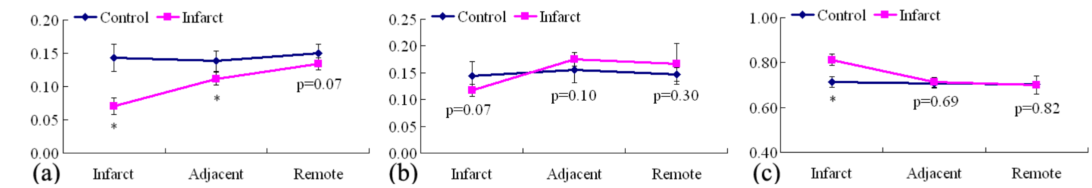

Fig.3 Comparison of Cl (a), Cp (b) and Cs (c) between infarct and control hearts at three regions. *p<0.05

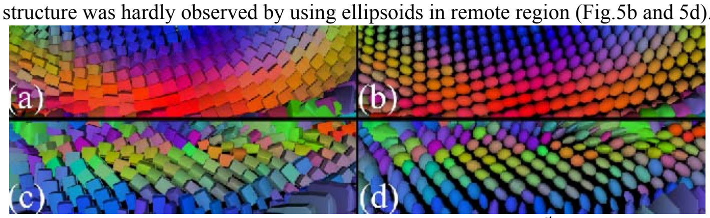

Fig.4 Laminar sheet structure at adjacent region in control (1st row) and infarct (2nd row) hearts visualized with superquadric glyphs (a, c) and ellipsoids (b, d).

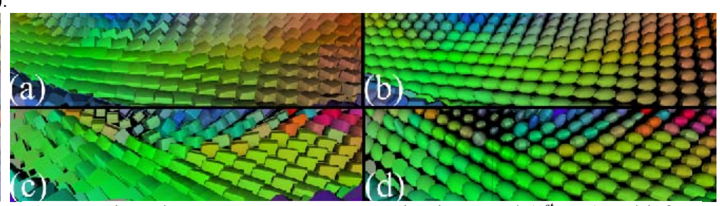

Fig.5 Laminar sheet structure at remote region in control (1st row) and infarct (2nd row) hearts visualized with superquadric glyphs (a, c) and ellipsoids (b, d).

Discussion

In current study, septum infarction was created on porcine models, with which diffusion tensor shape and structure of myocardium laminar sheet were explored. Significant change of tensor shape, including decrease of Cl and increase of Cs, was observed in both infarct and adjacent regions, which may due to myocardial fiber tearing and swelling [3-4]. No apparent change of the three anisotropies was found in remote region, which are consistent with the results of previous studies that no substantial change of diffusivities and diffusion anisotropy occurred in remote region [3-4]. Myocardium laminar structure was examined in adjacent and remote regions using superquadric glyphs and ellipsoids, respectively. The superquadric glyphs were found to provide better visualization of sheet structure as reported previously [6]. In infarct heart, myocardium laminar sheet structure was difficult to be distinguished in adjacent regions, which may be due to myocardial fiber tearing with extended formation of fibrosis [3-4]. Apparent alteration of laminar sheet structure was observed in remote region, which may be associated with the variation of fiber architecture as reported in [2-4]. In conclusion, both tensor shape and laminar sheet structure of infarcted heart differed substantially from those of controls, and these structural degradations are likely responsible for the deterioration of cardiac function. The current study demonstrates the ability of superquadric glyphs to detect myocardium structural degeneration and provides supplemental information for infarcted heart remodeling.

References [1] Chen J et al, AJP Heart Circ Physiol, 2003; [2] Wu MT et al, Circulation, 2006; [3] Wu Y et al, MRM, 2007; [4] Wu Y et al, JMRI, 2009; [5] LeGrice I et al, Interstitial Fibrosis in Heart Failure, Springer New York, 2005; [6] Ennis DB et al, MRM, 2005