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Meeting abstract

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1081 Toroid-based characterization of myocardial structure using diffusion tensor magnetic resonance imaging

Choukri Mekkaoui*[1], Marcel P Jackowski[2] and Albert J Sinusas[1,3]

Address: [1]Yale University, New Haven, CT, USA, [2]University of São Paulo, São Paulo, Brazil and [3]Yale University School of Medicine, New Haven, CT 06520-8017, CT, USA

* Corresponding author

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Introduction

Diffusion Tensor Magnetic Resonance Imaging (DT-MRI) is a noninvasive technique capable of characterizing cardiac fiber orientation and architecture [1,2]. The counter-wound helical organization and anisotropic nature of myofibers require efficient strategies for visualization and analysis. In this work, a new toroid-based representation of DT fields is used to create an improved depiction of myofiber orientation and derive a new diffusivity map, the toroidal volume (TV). The methodology is applied on canine hearts to characterize regions of tissue structure in normal and pathological states.

Purpose

Representation of myocardial macrostructure with DT-MRI can provide insights into myocardial remodeling after injury. The toroid-based representation of DT fields enhances 3D visualization of cardiac tissue architecture and provides a structural map (TV) for the analysis of normal and infarcted myocardium.

Methods

The toroid-based representation of the DT is described by the modified parametric equation of an elliptical torus. The length of the toroid represents the major eigenvalue, the ring the medium and the cross-section depicts the minor eigenvalue. A subset of toroidal shapes is then produced according to the local eigensystem. The TV map is subsequently defined by the volume of the local toroids. After the animals were euthanized, hearts were excised and perfused with saline solution. Each heart was then placed and positioned in a container and filled with Fomblin (Ausimont, Thorofare, NJ). DT-MRI data were collected with a 3.0-T Siemens-Trio-scanner (Erlangen, Germany) using a segmented EPI sequence. An icosahedral gradient-scheme containing 6 directions was applied with a constant b-value = 600 s/mm^2. A single image with a b-value = 0 s/mm^2 was also obtained. Fifty short-axis 2 × 2 × 2 mm slices were acquired with TR = 5400 ms and TE = 84 ms. In order to increase SNR, 48 averages were done (EPI factor = 7), totaling 6 hours of acquisition time. Toroid-based representation was applied on a normal heart and compared to ellipsoidal and superquadrics [3]. TV maps were calculated and compared to mean diffusivity (MD).

Results

Figure-1A shows a short axis T2-image at the mid-ventricles of a normal heart. Figure-1B shows the toroidal representation compared to ellipsoids (Figure-1C) and superquadrics (Figure-1D). The helical fiber arrangement is easily identified with toroids, but is more challenging to visualize with ellipsoids. Toroids appear to highlight the laminar architecture as seen by the changing orientation of fiber angles from epicardium to endocardium. The homogeneity of fiber structure of a normal heart can be observed by the homogeneity of the TV (Figure-2A) and MD (Figure-2B). Figure-2C depicts a substantial increase in TV on the infarcted heart. This increase indicates significant tissue alterations associated with myocardial infarction. In contrast, the infarcted region exhibits less apparent changes in signal intensity on the MD map (Fig-

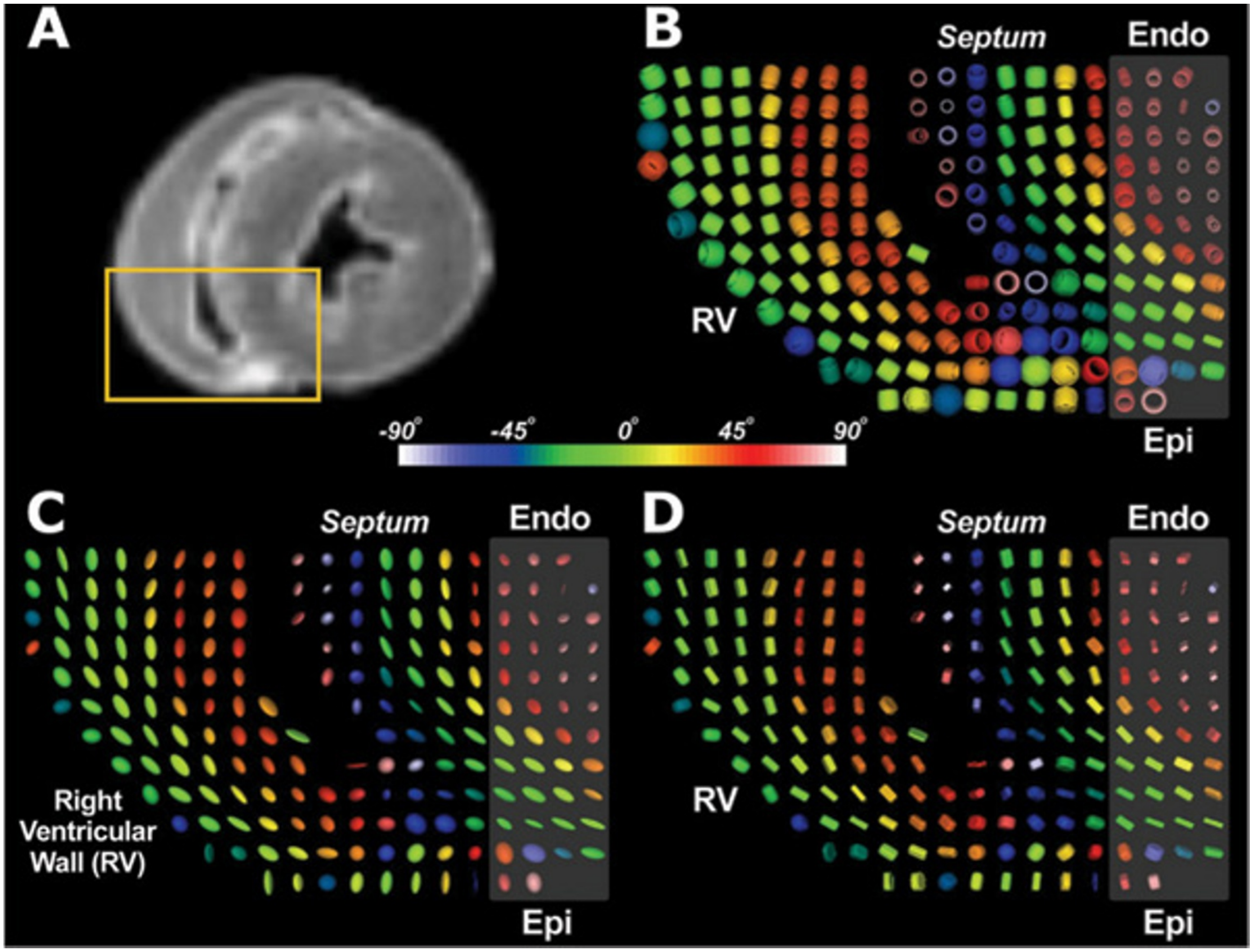

Figure 1

(A) Mid-ventricular T2-weighted image of a normal canine heart. The yellow rectangle represents the ROI for glyph visualization. Glyph shapes are coloured according to the fiber inclination angle as defined by Scollan. The toroidal glyph field is shown in **(B)**, ellipsoidal in **(C)** and superquadric in **(D)**.

ure-2D). Figure-3A shows the cross-sections of a T2-weighted image depicting the infarcted region. As shown in Figures-3B and -3C, architectural homogeneity degrades in the infarcted region, defined by a substantial increase in TV and more vertically-oriented fibers, respectively.

Conclusion

Characterization of cardiac tissue using DT-MRI relies on effective analysis and visualization methods. The toroid-based representation is less prone to visual ambiguity since toroids have genus 1 and concomitantly offers a new quantitative scalar map that enhances the understanding of the underlying myocardial structural properties.

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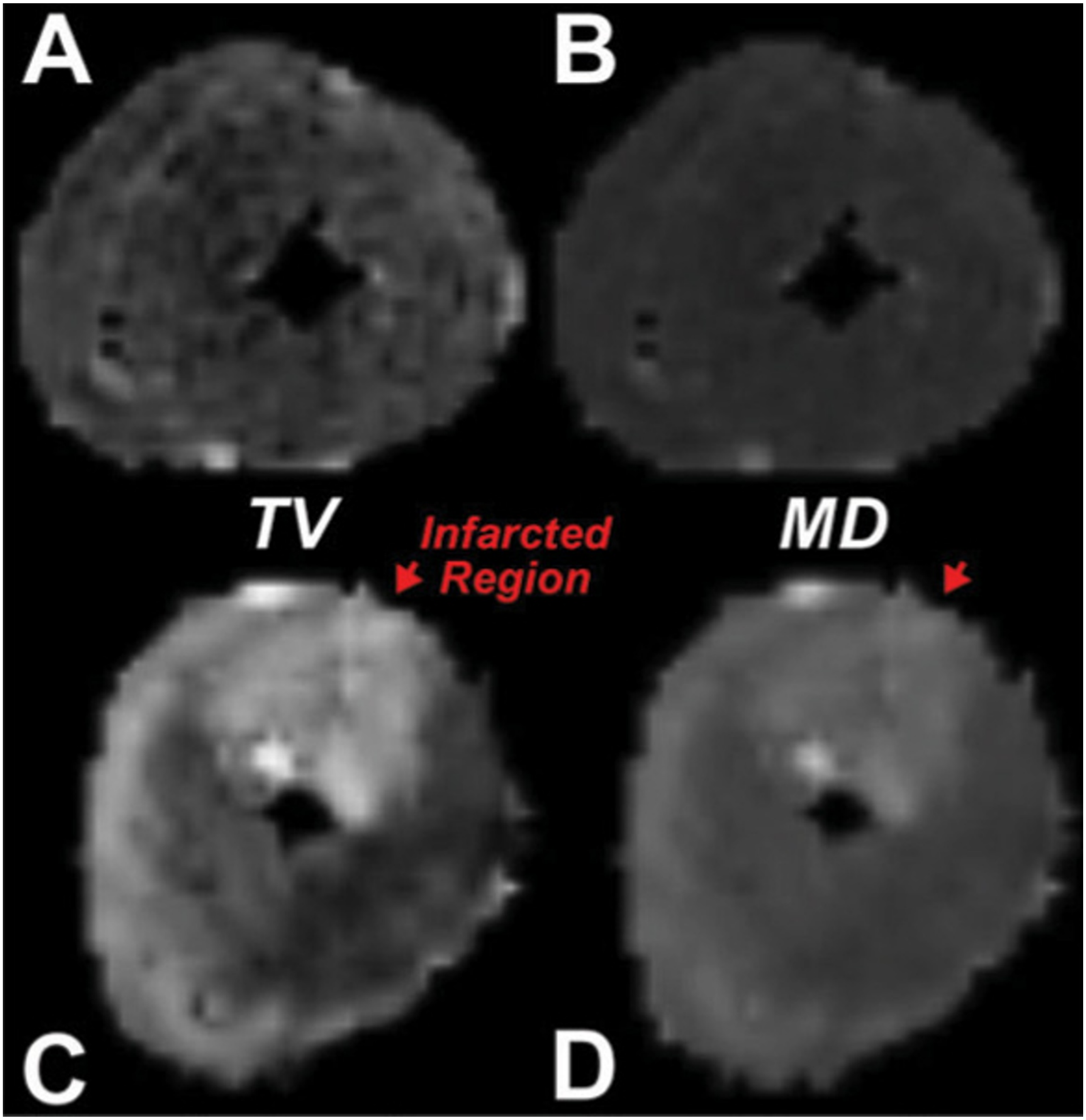

Figure 2
A mid-ventricular short-axis slice of normal and infarcted heart was chosed for compating TV and MD. TV **(A)** and MD **(B)** map of the normal heart. TV **(C)** and MD **(D)** map of the infarcted heart. The transition between normal and infarcted tissue is more evident in the TV map than in MD.

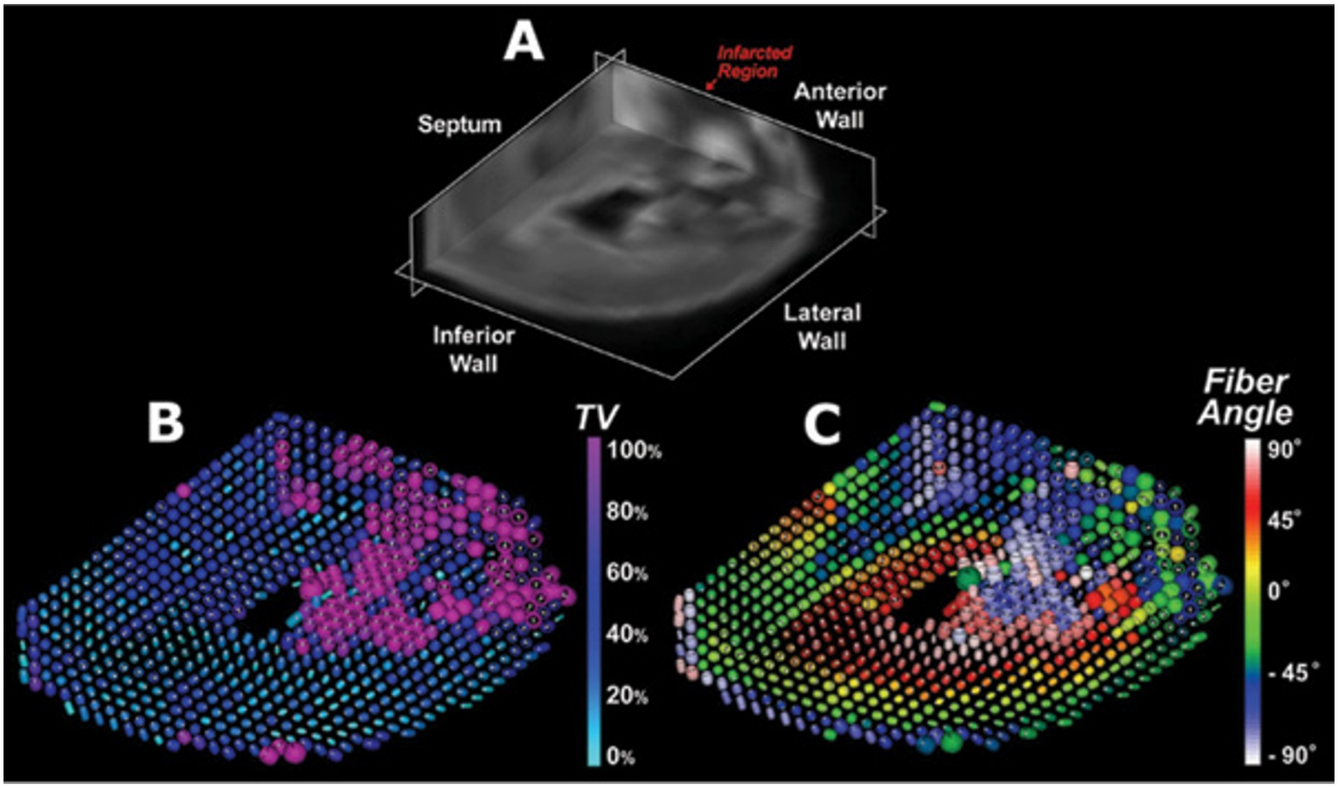

Figure 3
(A). Orthogonal cross-section of a T2-weighted image depicting an infarcted canine myocardium. **(B)** Toroidal glyph field color-coded with TV (%). **(C)** Toroidal field color-coded with the fiber inclination angle. Notice the rearrangement of fiber orientation within the infarcted region into a more vertical pattern as shown by the lighter blue and red toroids.