

A composite visualization method for electrophysiology-morphous merging of human heart

Fei Yang, Lei Zhang, Weigang Lu, Yue Zhang, Wangmeng Zuo, Kuanquan Wang, and Henggui Zhang

Abstract—Background: Electrophysiological behavior is of great importance for analyzing the cardiac functional mechanism under cardiac physiological and pathological condition. Due to the complexity of cardiac structure and biophysiological function, visualization of a cardiac electrophysiological model compositively is still a challenge. The lack of either modality of the whole organ structure or cardiac electrophysiological behaviors makes analysis of the intricate mechanisms of cardiac dynamic function a difficult task. This study aims at exploring 3D conduction of stimulus and electrical excitation reactivity on the level of organ with the authentic fine cardiac anatomy structure.

Methods: In this paper, a cardiac electrical excitation propagation model is established based on the human cardiac cross-sectional data to explore detailed cardiac electrical activities. A novel biophysical merging visualization method is then presented for biophysical integration of cardiac anatomy and electrophysiological properties in the form of the merging optical model, which provides the corresponding position, spatial relationship and the whole process in 3D space with the context of anatomical structure for representing the biophysical detailed electrophysiological activity.

Results: The visualization result present the action potential propagation of the left ventricle within the excitation cycle with the authentic fine cardiac organ anatomy. In the visualized images, all vital organs are identified and distinguished without ambiguity. The three dimensional spatial position, relation and the process of cardiac excitation conduction and re-entry propagation in the anatomical structure during the phase of depolarization and repolarization is also shown in the result images, which exhibits the performance of a more detailed biophysical understanding of the electrophysiological kinetics of human heart in vivo.

Conclusions: Results suggest that the proposed merging optical model can merge cardiac electrophysiological activity with the anatomy structure. By specifying the respective opacity for the cardiac anatomy structure and the electrophysiological model in the merging attenuation function, the visualized images can provide an in-depth insight into the biophysical detailed cardiac functioning phenomena and the corresponding electrophysiological behavior mechanism, which is helpful for further speculating cardiac physiological and pathological responses and is fundamental to the cardiac research and clinical diagnoses.

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Keywords: Computational cardiology, Morphous Biophysical merging, Cardiac biophysiological function, Merging attenuation model

1 BACKGROUND

The cardiac disease, e.g., atrioventricular block, ventricular fibrillation and cardiomyopathy, is one of the most common causes of mortality in the world. It has been proven that cardiac functional abnormality may produce the serious problem of heart disability and are generally life-threatening [1]. Although there are considerable progresses have been achieved on conventional open-heart research and acquirement of experimental and clinical data, the cardiac mechanisms aren't well understood. Increasing mo-

mentum is tending to study the cardiac biophysiological function noninvasively [2], [3], [4]. Serpooshan et al. [5] analyzed the structure and function of the failing heart to enhance cardiac healing after injury. Zhang et al. [6] visualized cardiac microvessels embolization in 3D space with X-ray phase contrast images. This method was beneficial to diagnoses and predicting and judging the prognosis in myocardial infarction (MI). Based on the surface shape space Taimouri and Hua [7] et al. defined two novel shape descriptors by the geodesic distance connecting two points in the two cardiac medial surfaces, which quantitatively analyzed the similarity and disparity of the 3D heart motions between the healthy and myopathic subjects and accurately detected myopathic regions on the left ventricle. Spicher et al. [8] proposed a new cardiac triggering method to estimate the cardiac cycle phase in real-time from videos captured with an in-bore camera. However, the function mechanisms and the underlying genesis of human heart still remain unclear.

Electrophysiological behavior is of great importance for analyzing the functional mechanism under cardiac physiological and pathological condition. Noble [9] first applied the cell mathematical model-HH model to the purkinje fibre and pace-maker cells and started the research on

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