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Left Atrial Image Registration to Guide Catheter Ablation of Atrial Fibrillation: In the Eye of the Technology

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Introduction

PAtrial fibrillation is a common arrhythmia, and its incidence rise sharply with age and with heart failure.Since the beginning of the new millennium, the debate on ectopic foci versus reentry as the mechanism underlying atrial fibrillation (AF) in humans has continuously evolved. The finding of ectopic beats proceeding from the pulmonary veins in the initiation of atrial fibrillation gave a different approach to the therapeutic management of this arrhythmia.[1-4] Recently, the mechanism of AF is considered to be a spiral wave with a continuously changing pattern of the activation wavefront, that is, a random multiple reentry of independent wavelets wandering in the atria around arcs of refractory tissue[5-10] or the accentuation of focal activity originating mainly from the pulmonary veins, the superior or inferior vena cava, the ligament of Marshall, or even the right atrium.[11-17]

The medical treatment of atrial fibrillation with antiarrhythmic drugs, either to control rate or rhythm, is not adequate for all patients and is frequently associated with pharmacological adverse effects.[18-20] Therefore, the number of therapeutic procedures for atrial fibrillation with catheter ablation is rapidly increasing. Since the demonstration of spontaneous initiation of atrial fibrillation by ectopic beats originating from the pulmonary veins, transvenous catheter ablation has become the most exciting and innovative field of interventional electrophysiology.[21-24] However, due to the complex and variable anatomy of atrial structures and pulmonary veins, the success rate of atrial fibrillation ablation is still not ideal, and the association with procedural complications still remains a problem. The left atrium and the pulmonary veins can not be seen with fluoroscopy because they do not present contrast against the surrounding structures. Even with advance techniques to minimize fluoroscopy time and radiation exposure, it is of concern the significant ionizing radiation exposure during prolonged fluoroscopy required to delineate the complex anatomy of the left atrium and the pulmonary veins. Besides, there are multiple variations of pulmonary veins anatomy which include different sizes, a common right or left ostium, and an additional pulmonary vein. Thus, more accurate imaging modalities and their combination are likely to overcome these difficulties and improve ablation success and related safety.

The current standard computer navigation tool used during AF catheter ablations is the electroanatomic mapping, which detects the tip of the catheter in real time.[25-27] The key step in the clini-

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cal use of three dimensional (3D) surfaces is image registration. The surfaces from axial computed tomography (CT) and nuclear magnetic resonance (MR) can only be useful during an ablation procedure if they can be accurately overlaid with the electroanatomic mapping, so that real-time catheter positions can be shown in precise relation to the 3D surfaces.[28-30] Currently available cardiac mapping systems can record cardiac electrical activation information, catheter and lesion location, and are capable of tracking catheters in real time. Combining this electrical and navigational information with the explicit three dimensional anatomy of the left atrial chamber and pulmonary veins, through this process called registration, should increase the efficacy of atrial fibrillation ablation procedures.[31-34] In this issue of the journal, Jasbir Sra reports detailed data on the basic principles, the inherent limitations, and the fundamentals of cardiac image registration.[35] He addresses the different 3D anatomical mapping and imaging systems and their clinical applicability in combination, as well as, the clinical studies utilizing the registration imaging technique. The validity of applying the registration process within the particular constrains of cardiac imaging is also examined. Imaging registration is the process of combining and aligning various images obtained with different imaging modalities. Proper imaging and segmentation involves establishing a correspondence between the spatial information in the image and the equivalent anatomical structure in the heart. Several imaging modalities have been used in an attempt to delineate cardiac structures, namely, contrast fluoroscopy, 3D electroanatomical noncontact mapping, 3D axial computed tomography, and 3D nuclear magnetic resonance. The registration process determines the geometric transformation that aligns anatomical features in one view of an object with the corresponding anatomical features of the same object in another view. It allows real-time visualization of anatomical structures and more accurate tracking and location of the mapping and ablation catheter, this translates into a significant clinical implication in the interventional treatment of atrial fibrillation.[31-34]

Several recent experimental and clinical studies demonstrated the accuracy of targeted ablations guided by cardiac image registration.[36-40] It was shown that registration can be successfully used for the anatomically correct extraction and reconstruction of the left atrium and pulmonary veins anatomy, allowing tailored radiofrequency ablation to individual pulmonary vein and left atrium anatomy during atrial fibrillation ablation procedures. Whether the improvement of catheter navigation by the imaging registration techniques can translate into better outcomes of AF ablation and avoid procedure-related major complications needs to be determined by larger randomized clinical studies.

The necessity to combine various imaging modalities like fluoroscopy, electroanatomic mapping, 3D CT-MR, and intracardiac echocardiography guidance, to optimize the results of atrial fibrillation ablation implies the technical difficulties in performing this therapeutic approach. On the other hand, the necessity to combine different ablation techniques, namely, circumferential, linear, and targeted ablation of complex fractionated electrograms, in order to improve the success rate demonstrates the complexity of the electrophysiological substrate in atrial fibrillation.

A detailed colorful picture can tell more than words can say. There is no doubt that a new hope emerges with a new tool, and left atrial image registration for catheter ablation of atrial fibrillation certainly provides us with a newer landscape in the horizon, but here again, it has to stand the test of time.

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