Real-time imaging in electrophysiology: from intra-cardiac echo to real-time magnetic resonance imaging

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Received 25 February 2009; accepted after revision 2 March 2009; online publish-ahead-of-print 9 April 2009

This editorial refers to ‘Electroanatomic properties of pulmonary vein antral regions enclosed by encircling ablation lesions’ by D. Schwartzman and J.L. Williams, in Europace 2009;11(4):435–444.

Interventional electrophysiology using catheter ablation is a rapidly growing field that has allowed for the cure of arrhythmias originating from every cardiac chamber as well as the great vessels. The keys to the success of the ablation procedure are targeting critical areas required to initiate and sustain the arrhythmias as well as insuring the delivery of effective ablation lesions. Understanding the intricate relationship between the anatomical structures and their functional relationship to the arrhythmia, or the ‘electro-anatomical substrate’, represents the greatest limitation to the success of the ablation procedure. For atrial fibrillation, the electro-anatomical substrate largely consists of the posterior wall of the left atrium which includes the pulmonary vein antra,¹ and most operators aim for at least electrical isolation of the pulmonary veins and consider this to be an acceptable endpoint for the procedure.²,³

Several technological tools are currently available to guide catheter navigation with more advances coming down the pipeline. When used in combination, these have made ablation procedures safer, shorter, and more successful.⁴ These include X-ray fluoroscopy, electro-anatomical mapping systems with image integration capabilities, and intra-cardiac ultrasound, in addition to the standard intra-cardiac electrogram recordings. Currently, X-ray fluoroscopy and intra-cardiac echo are the only widely available modalities that can provide real-time imaging that can be readily used during the procedure.

Fluoroscopy is inherently associated with significant radiation exposure to the patient and operator. In addition, the images obtained are two-dimensional projections of three-dimensional structures and cannot localize ablation lesions. This limits its desirability for the guidance of complex ablation procedures. Electro-anatomic systems’ limitations relate to the inaccuracies in image acquisition and registration.⁵ The other widely used real-time imaging modality is intra-cardiac echocardiography (ICE). Two ICE catheters are commonly used in electrophysiology procedures. One system is a 10 F catheter-based phased-array transducer operating at 5.5–10 MHz frequency, with Doppler capabilities. It allows longitudinal 90° sector imaging with a radial depth penetration of 4 cm. It is a steerable catheter with up to 12 cm depth penetration allowing visualization of left-sided structures from the right side of the heart. Recent advances permit three-dimensional reconstruction and image integration with electro-anatomical mapping.⁶ In addition, this catheter can be used to visualize and quantify micro-bubble formation in the left atrium during ablation.⁷

A second ICE catheter system is used in this study. It utilizes an 8 F mechanical intravascular ultrasound catheter that incorporates a 9 MHz beveled single-element imaging transducer. This catheter obtains cross-sectional images perpendicular to its long axis and allows three-dimensional reconstruction.

In this issue of Europace, Schwartzman et al.⁸,⁹ used intravascular ultrasound to define enclosed regions of interest surrounding the pulmonary vein ostia. Using this technique, the placement of ablation lesions encircling the designated regions of interest was successful in all patients. This was verified by the reduction in the amplitude of the measured local electrograms to <10% of their pre-ablation amplitude.

When entrance and exit block was tested into and out of the enclosed regions, the area of interest surrounding the left-sided pulmonary veins was less likely to be electrically isolated compared with the area of interest surrounding the right-sided veins and one or more additional lesions were required to achieve electrical isolation. The authors go on to correlate the observed electrogram patterns within as well as outside the enclosed regions to the anatomical landmarks of the left atrium. Prominent on the left side is the left atrial appendage, which has a complex and variable relationship to the left-sided pulmonary

The opinions expressed in this article are not necessarily those of the Editors of Europace or of the European Society of Cardiology.

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veins and inter-atrial conduction system. Around the right-sided veins, entrance and exit block to and from the enclosed regions relates anatomically to the cavo-atrial junctions, the inter-atrial bundle, and the inter-atrial septum.

The muscular sleeves from both right- and left-sided veins circumferentially merge into the left atrium. The left atrial wall becomes progressively thicker more centrally from the vein ostia. The increased thickness makes it more difficult to place transmural ablation lesions especially without using an irrigated-tip catheter. The authors acknowledge this limitation and report that the site of additional lesions required to achieve electrical isolation was not found to be along the lines of prior ablation, arguing that their initial lesions were transmural.

In summary, this article provides valuable insights into the electro-anatomical relationship in the paroxysmal and persistent atrial fibrillation substrate, further highlighting the importance of understanding this complex interaction to improve safety and outcomes in atrial fibrillation ablation.

The way of the future in imaging in electrophysiology will combine real-time catheter guidance and lesion formation. Very promising in this regard is magnetic resonance imaging. It provides outstanding soft tissue characterization without damaging ionizing radiation. New sequence acquisition codes allow for the detection of lesions as soon as they are placed. This allows the assessment of transmurality as well as the damage to neighbouring structures including the oesophagus. Magnetic resonance imaging (MRI) compatible catheters are being developed to allow for real-time catheter navigation to key target areas in the heart. In addition, this all takes place in the absence of any ionizing radiation to the patient and operator. Moreover, the incidence of nephrotoxicity with MRI contrast is much less common than that associated with the use of iodinated contrast agents.1,10

Conflict of interest: none declared.

References