Editorial

Seeing is believing: visualization of pulmonary vein gaps using ultra-high resolution electroanatomic mapping

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Atrial fibrillation (AF) is the most common cardiac arrhythmia. Given the increase in the aging population, the prevalence will potentially double in the coming 5 decades (1). Haissaguerre *et al*. (2) and Chen *et al.* (3) firstly reported the dominant and pathologic role of pulmonary vein (PV) triggers as being responsible for the arrhythmogenesis of AF. Owing to the advancement of mapping techniques and understanding of the pathogenesis, catheter ablation has been considered as an effective and alternative treatment option for AF patients, and a complete electrical PV isolation (PVI) is the current Class I recommendation (4). Although numerous techniques and ablation strategies have been explored and investigated to improve the durability of ablation lesions, the recovery of the PV conduction, which accounts for up to 80% of AF recurrences during the second procedure, remains the leading cause of AF recurrences (5,6). Once the PVs are electronically reconnected, ablation by targeting the conduction PV gaps to achieve a complete re-isolation is crucial (4). In spite of the evolution of materials and navigation systems, circular mapping catheters have exclusively been applied to evaluate the left atrium-PV (LA-PV) conduction and PV reconnections for almost the past 20 years. However, the complexity of the scar derived from a previous ablation line and the weak electrogram features can contribute to the interpretation of the PV gaps, and as a consequence, the clinical hurdle during a repeat AF ablation.

In the issue of Heart Rhythm, Masuda *et al*. (7) prospectively enrolled 31 consecutive patients undergoing a second ablation with identifiably reconnected conduction at any of the four PVs after a prior PVI. The authors postulated the reconnection of the PV gaps could be better recognized by a new ultra-high resolution electroanatomic mapping system [Rhythmia®, Boston Scientific, Marlborough (Cambridge), MA, USA] using the Orion® catheter (Boston Scientific), a 64-pole small basket catheter. The results demonstrated that the new electroanatomic mapping system could facilitate the visualization of 54 reconnected gaps in 39 ipsilateral PV pairs along the previous PVI lines. Of them, 31 (57%) gaps could be visualized directly on the propagation map, while manual electrogram re-annotation was required for the remaining 23 (43%) gaps, which were more frequently located at the anterior and carinal regions than the other regions.

Notably, at the crossover point between the gap pathway and encircling PVI line, the 3.5-mm tip ablation catheter failed to record any local electrograms in 20% of the gaps obtained from ultra-high resolution mapping. The authors used the traditional circular catheter as the gold standard to evaluate a successful PVI. Ablation of these gaps, defined by ultra-high resolution mapping, contributed to either the alteration of the activation sequence or the elimination of the PV potentials, implying neither an overestimation nor underestimation of these gaps. Nevertheless, in spite of an attempt to adjust the lower limit of the voltage threshold by starting with 0.20 mV and a substantial decrement of 0.02 mV, the voltage map could not identify the gap location in the majority (65%) of these gaps.

The efficacy of detecting LA-PV reconnections in this study was better than that of the previous report. Anter *et al.* (8) demonstrated that PVIs were underestimated by the Orion catheter in 9% of PVs, while the Lasso catheter in conjunction with pacing maneuvers overestimated it in 21% of PVIs. Differing from the present study, patients that underwent an index or repeat procedure were included. The definition of the primary endpoint was based on the comparison between the recorded electrograms and reality of the PV connection through pacing maneuvers, which may explain the diverse effectiveness in these two studies. Moreover, despite the fact that Orion improved the recording of the PV potentials after an incomplete isolation, the false-positive identification of PV-like potentials from nearby structures was increased. Far-field signals in the anterior and carinal regions could be derived from the activations of the left atrial appendage, superior vena cava, ligament of Marshall, and right atrium, and a specific maneuver might be required to differentiate within these areas (9-11). Similar to the study by Kosiuk *et al*. (12), manual adjustment of the window from an incorrect automatic annotation of a far field signal to a delayed and/or separated local PV potential was necessary for the delineation of the conducting gaps, which might possibly lead to a longer procedural or fluoroscopy time.

There are differences between the Orion and Lasso catheters. The Lasso circular catheter has 20 electrodes with a 1 mm2 surface area, 3 mm interelectrode spacing, and maximal diameter of 25 mm, while the Orion basket has 8 splines with 8 electrodes on each spline (total 64 electrodes), surface area of 0.4 mm2, interelectrode spacing of 2.5 mm, and maximal diameter of 22 mm. The above electrode differences will translate into not only more accurate and higher density electroanatomic maps, but also a higher resolution and better sensitivity to near field signals by the Orion catheter than conventional mapping (13). Through the use of the Orion catheter, the gap could be evaluated by a wavelet propagating into the PVs by ultra-high resolution mapping.

Additionally, there are several additional issues to be addressed in the future investigation of this novel mapping catheter and navigation system. First of all, Bisbal *et al*. (14) studied the correlation between the electrical PV reconnections and delayed-enhancement cardiac magnetic resonance (DE-CMR)-based PV gap identification. The result demonstrated that the electrical PV reconnection sites identified by a circular catheter were matched with the gaps recognized by the DE-CMR in 79% of PVs. Whether the electrical reconnections identified by the ultra-high resolution map could have better agreement with the DE-CMR findings remains unknown. Second, the authors studied the identification of the PV gaps during repeat procedures in AF patients. Whether the application of the ultra-high resolution map during the index or repeat AF ablation procedure can bring better clinical outcomes and less recurrence needs future investigation.

In summary, the advancement of signal processing systems and mapping catheters, as well as the significant improvement in the mapping density and quality, has led to a pivotal breakthrough in the identification of PV gaps during repeat AF ablation procedures. Future investigation will be warranted regarding AF recurrences through the application of the ultra-high resolution mapping system.

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Footnote

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