A Ripple in Time: Timing is Everything

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Editorial

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Catheter ablation is an established and effective treatment modality for management of drug refractory symptomatic outflow tract premature ventricular contractions (PVCs). However, identification of the true site of origin when mapping is key for a successful ablation. Outflow tract PVCs may originate from the epicardium [left ventricular (LV) summit], endocardium [left or right outflow tracts (LVOT and RVOT)], or mid-myocardium (intramural). There are currently no clear ECG criteria identified to definitively indicate an intramural origin of outflow tract PVCs. The traditional approach to mapping the PVC origin entails a combination of pace-mapping as well as activation mapping. The latter consists of assigning a local activation time to each point relative to a fixed reference, and identifying the earliest, pre-QRS ventricular signal.

The widespread adoption of multipolar mapping catheters has heralded innovative and novel approaches to performing automated, high-density activation mapping of PVCs. Activation mapping of outflow tract PVCs can sometimes be challenging for various reasons. Manual annotation of activation times is often required, rendering the process arduous and time-consuming. Assigning earliest signal in areas of scar or conduction slowing may be arbitrary and challenging due to low-amplitude multi-component electrograms (EGMs) in those areas. Low-amplitude EGMs may also represent far-field potentials in adjacent tissue, such as mid-myocardial PVCs originating from deeper in the septum or in the opposite chamber.[1] These EGMs would be excluded from activation mapping, increasing procedural failure rate due to ablation at PVC endocardial breakout sites rather than at its more distal site of origin.

Ripple mapping (Biosense Webster, Irvine, CA) was developed to remedy the short-comings of traditional activation mapping,[2]and has been validated for ventricular tachycardia, atrial flutter and atrial tachycardias (AT).[3–5] Ripple maps provide real-time display of dynamic bars of varying heights depending on the amplitude of the local EGM over time, and ideally would obviate the need for manual annotation or interpolation over unmapped myocardium.[6] By displaying the entirety of the EGM over time, Ripple mapping allows the operator to identify potentially relevant far-field sites such as mid-myocardial or epicardial PVC foci, or delayed conduction in regions of scar.[4] The Ripple-AT study randomized 83 patients with AT to Ripple mapping vs isochronal activation mapping and demonstrated higher rates of AT termination with the

former.[3] In patients with arrhythmogenic right ventricular cardiomyopathy, complete ablation of conduction channels identified using Ripple mapping led to improved rates of VT-free survival during follow-up.[4]

In this issue of the *Journal,* Arps et al evaluated the utility of Ripple mapping as an adjunct to activation mapping during ablation of septal outflow tract PVCs. In a series of 55 patients undergoing PVC ablation in the LVOT or posterior RVOT, their study retrospectively compared the earliest activation point (EA) obtained with activation mapping to the earliest Ripple signal (ERS) on Ripple mapping and to successful ablation points. Mapping was done in both chambers in most patients, including the coronary sinus in half the cohort. Chamber concordance between ERS and EA was found in 88% of cases and was associated with higher rates of successful PVC suppression. Distance between EA and ERS was associated with procedural success and was >5 mm in 52% of cases. Discordance was more likely in patients who had prior PVC ablation and was associated with higher rates of requiring multi-site ablations. Interestingly, there was no difference in the distance between EA vs. ERS with sites of successful ablation, albeit analyzed in a small subset of patients. We congratulate Arps et al. for their well-written, clinically valuable manuscript. As evidenced by the study results, Ripple mapping may improve localization of septal outflow tract PVCs beyond traditional activation alone. Discordance between EA and ERS may suggest mid-myocardial or epicardial PVC focus, seen as far-field low-amplitude EGMs on Ripple mapping. This finding should prompt the operator to perform more extensive mapping beyond LV and RV endocardium to identify more distal PVC foci.[7] With the more recent availability of better tools to map the coronary venous system, the ability to identify the intramural substrate for the difficult to reach locations in the outflow tract region has further improved the success of ablation in this region.

The study by Arps et al. raises important questions that require further research. The retrospective nature of this study limits clinical applicability of the results due to potential confounders such as operator experience, point sample density, type of mapping catheters, variable intra-procedural use of Ripple mapping, etc. Larger prospective studies are needed to validate the impact of Ripple mapping on PVC ablation outcomes. Furthermore, whether early low-amplitude fractionated Ripple signals represent near-field scar or far-field mid-myocardial PVC requires more investigation. Operators need to be aware of the shortcomings of Ripple mapping technology such as influence of catheter orientation or underlying rhythm on EGM amplitude, its dependence on density of mapping points obtained, potential interference from noise artifact, and potential subjectivity in interpreting Ripple signals.

In conclusion, Arps et al. introduce Ripple mapping as an additional tool in the armamentarium to localize the site of origin of PVCs and the potential impact on the ablation strategy, particularly for mid-myocardial or epicardial outflow tract PVCs where traditional activation mapping may be inadequate or particularly challenging. As this study shows, neither approach in isolation is sufficient. To achieve procedural success, electrophysiologists should always remain vigilant to the nuances of the raw EGM rather than blindly relying on automated algorithms provided by mapping systems. A comprehensive understanding and analysis of ECG characteristics of the outflow tract region PVCs, understanding the anatomy of the outflow tract region including the surrounding coronary venous system, coupled with the use of imaging modalities such as intracardiac echocardiography and cardiac MRI, and high density mapping, further enhanced by the use of mapping technologies such as Ripple mapping to provide functional as well as anatomic information could further improve the safety and efficacy of ablation of outflow tract PVCs.

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