Case Series

EPS RFA for SVT due to redo-accessory pathways using advanced open window 3D electro-anatomical mapping

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1. Introduction

Accessory pathways (APs) are fibrous myocardial connections that enable direct electrical communication between the atrium and ventricle. These pathways function as alternate conduction routes, independent of the regulatory atrioventricular (AV) nodal conduction system and Purkinje fibers. They arise from incomplete isolation of the AV annulus during embryological development.[1,2] Single APs are significantly more common; however, multiple pathways are more complex and are associated with other cardiac conditions like Ebstein's anomaly[2,3] Accessory pathways allow extra nodal conduction anterograde (atrium to ventricle), retrograde (ventricle to atrium) or both. They are named for the anatomical structures they connect but are further classified by their type of conduction (decremental or non-decremental) and direction of conduction (anterograde or retrograde)[2] Anterograde conduction through an accessory pathway (AP) can depolarize ventricular tissue ahead of normal stimulation via the AV node. This is characterized on a baseline sinus ECG by a classic short PR interval (≤120 milliseconds) and an up-slurring pre-QRS feature known as a delta wave.

Radiofrequency ablation (RFA) is a commonly used procedure to treat accessory pathways, which are abnormal electrical connections between the atria and ventricles. The goal of RFA is to eliminate or modify these abnormal pathways, restoring normal electrical conduction in the heart. Intracardiac mapping of accessory pathways has advanced significantly, playing a key role in achieving high success rates for catheter ablation procedures. High-density mapping using the open window mapping (OWM) technique is a novel and alternative approach to mapping and ablating Aps.[6] Increasing point density in 3-dimensional electroanatomic mapping enhances the accuracy of substrate prediction and modeling, especially given the variability during atrioventricular (AV) accessory pathways. These pathways can have oblique atrial and ventricular insertion sites or exist as multiple pathways, which makes precise mapping more difficult.[5]

1.1 Problems in Redo-Accessory Pathway Ablation (Figure 1)

- Difficulty in deducing A & V signals
- Change in Accessory pathway electrophysiological properties
- Broad insertion of pathways
- Multiple accessory pathways

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- Annotation is difficult when dealing with complex signals - *Redo cases, Ebstein's anomaly*

1.2 Open Window Mapping

Open-window mapping (OWM) presents notable advantages over traditional mapping techniques by obviating the necessity of manually discerning atrial, ventricular, or pathway electrogram (EGM) signals, a task that can prove particularly challenging with widely spaced bipolar mapping catheters. In conventional mapping, the identification of these signals often depends on the operator's expertise. In contrast, OWM seamlessly integrates both atrial and ventricular EGM signals within the window of interest (WOI) and employs an algorithmic approach to automatically detect local signals exhibiting the maximum change in voltage over time (dV/dt). This automated process enhances both the efficiency and precision of mapping, facilitating more accurate identification of arrhythmic substrates.[6,7]

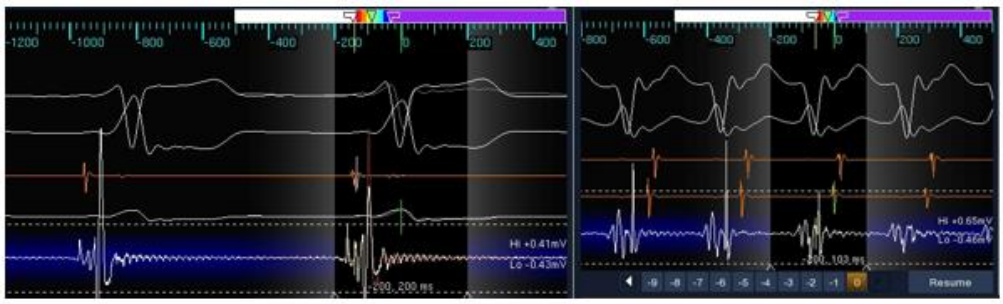

Fig (1): Intracardiac EGM describing difficulty in analyzing earliest V and A signal

2. Case Presentation

In this case series, 6 patients underwent invasive electrophysiology studies for accessory pathways utilizing the high-density open window mapping. All patients had normal heart structures, with the exception of two having Ebstein's anomaly.

	Location of Accessory Pathway
Patient 1	Right lateral
Patient 2	Ebstein's anomaly – Multiple pathways
Patient 3	Para-Hisian
Patient 4	Left antero-lateral
Patient 5	Left posterior
Patient 6	Ebstein's anomaly- Right lateral

Case 1: Right lateral Accessory pathway (Figure 2a, 2b)

A complex case of Wolff-Parkinson-White (WPW) syndrome with a right lateral accessory pathway was referred for further management after two prior unsuccessful ablation attempts. Initial diagnostic workup, including the baseline electrocardiogram (ECG), re-

vealed evidence of pre-excitation, while the tachycardia ECG demonstrated a regular narrow QRS complex tachycardia. Notably, the intracardiac electrograms (EGMs) exhibited fractionated ventricular (V) signals, likely a result of the previous ablation procedures.

The true manifestation of pre-excitation was confirmed through free wall pacing. High-density catheter mapping was performed across both the right atrium and right ventricle, providing a comprehensive view of the electrophysiological landscape. During the antegrade pre-excitation, both ventricular and atrial signals from the annular region were captured. In automap mode, annotations were generated using the dV/dt protocol, facilitating precise localization of the electrical activity. A significant finding during the mapping process was the detection of a signal leak at the 7 o'clock position in the tricuspid annular region. Additionally, the patient was diagnosed with orthodromic reentrant tachycardia (ORT), prompting the mapping of the entire cycle length of the tachycardia to evaluate its electrophysiological properties. Propagation mapping was subsequently performed, with a stepwise analysis confirming the presence of a leak at the 9 o'clock position of the tricuspid annulus. Based on these findings, the target site for ablation was identified with precision, and ablation was carried out at the suspected leak site. The procedure successfully terminated the tachycardia, leading to a positive clinical outcome. This case highlights the critical role of advanced Open window mapping techniques and detailed step-by-step analysis in identifying and addressing Redo ablation in WPW syndrome.

Fig (2a)

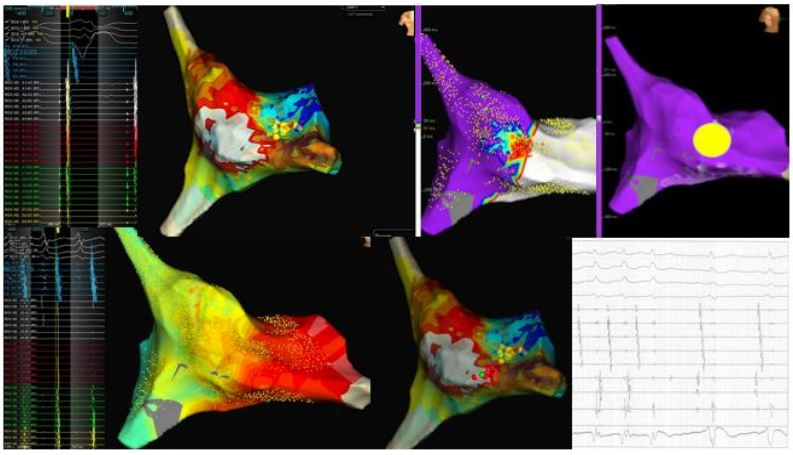

Fig (2b)

Fig (2): (2a) Baseline ECG demonstrates evidence of pre-excitation, Tachycardia ECG demonstrates a regular narrow QRS complex tachycardia after two prior failed ablations.

(2b) Intracardiac EGM demonstrating open window mapping of orthodromic reentrant tachycardia with right lateral accessory pathway

Case 2: Ebstein's Anomaly with Multiple Accessory pathway (Figure 3a,3b)

A 24-year-old male with a known case of Ebstein's anomaly presented with recurrent episodes of palpitations. Initial evaluation through electrocardiography (ECG) revealed a pre-excitation pattern, while the clinical tachycardia ECG demonstrated a wide complex tachycardia characterized by negative deflections in leads II, III, and aVF, and a left bundle branch block (LBBB) morphology in V1, with a rapid transition in V2. These findings were suggestive of antidromic atrioventricular reentrant tachycardia (AVRT) utilizing a right ventricular posteroseptal accessory pathway. During the electrophysiological study, two distinct morphologies of pre-excitation were identified. Pacing from the coronary sinus reproduced clinical morphology, reinforcing the diagnosis of antidromic AVRT mediated by the right ventricular posteroseptal accessory pathway. Conversely, pacing from the right atrial appendage resulted in a different morphology, with positive deflections in lead II and negative deflections in leads II and aVF, suggesting a distinct electrophysiological pattern. Easily inducible orthodromic AVRT with typical RBBB morphology was noted as suggestive of Ebstien's anomaly. Using High-density Catheter Open window mapping was done across both the right atrium and right ventricle. During pre-excitation, line of block was noted in the superior Tricuspid annulus and leak is found in the 5'O clock tricuspid annulus position. Leak in this region was also noted during tachycardia. Within the same pre-excitation there was additional leak noted in the 10'O clock tricuspid annulus position in the open window mapping. Radiofrequency (RF) lesions were delivered to the identified areas, and the right posteroseptal pathway was successfully ablated, leading to termination of the tachycardia.

Subsequent induction of the second tachycardia episode revealed no pre-excitation on the ECG. Mapping of the earliest signals in this tachycardia identified their origin at the lateral tricuspid annulus. Open window mapping revealed a leak at 11 o'clock position of the tricuspid annulus. RF lesions were delivered to this site, successfully terminating the tachycardia. Post-ablation, tachycardia was no longer inducible, and no pre-excitation was observed on the ECG, confirming the success of the intervention.

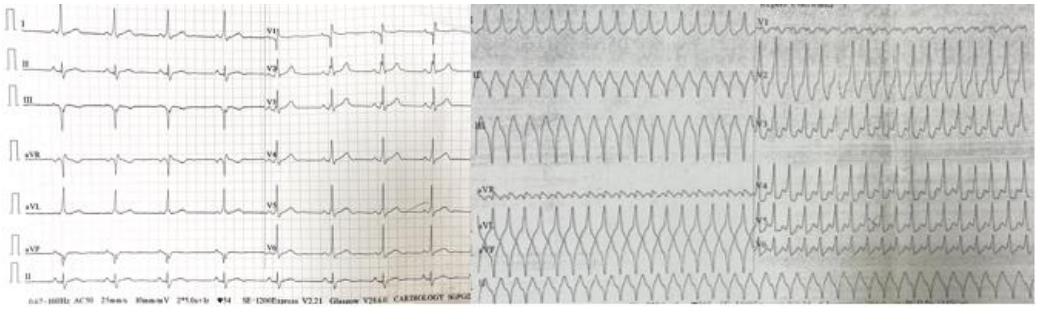

Fig (3a)

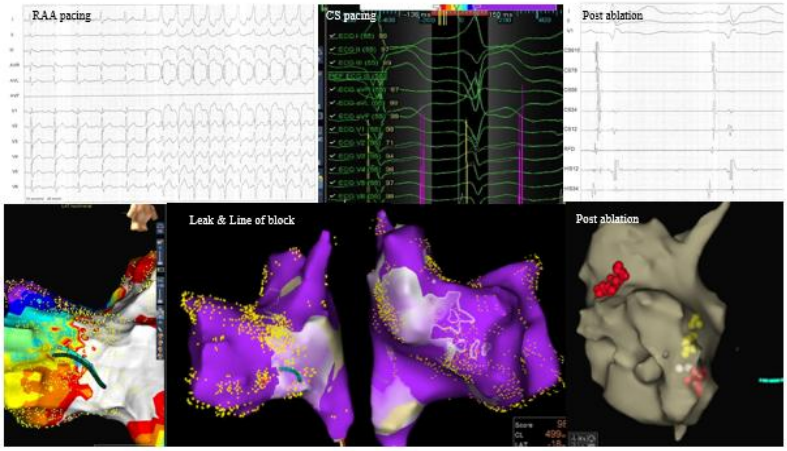

Fig (3b)

Fig (3): (3a) Baseline ECG demonstrating evidence of pre-excitation, Tachycardia ECG suggestive of Right posteroseptal accessory pathway. (3b) Intracardiac EGM demonstrating open window mapping in 3-D anatomical guidance of Ebstien's anomaly with multiple accessory pathway

Case 3: Para-Hisian Accessory pathway (Figure 4)

A case of a Para-Hisian accessory pathway was presented, with the baseline electrocardiogram (ECG) revealing a left bundle branch block (LBBB) morphology in lead V1, a transition in lead V2 and V3, and negative deflections in leads II and III. The diagnostic challenge in this case was the difficulty in distinguishing between the atrial (A) signal, ventricular (V) signal, accessory pathway potential, and His bundle potential due to the location of the accessory pathway near the His bundle. In the electrophysiology (EP) lab, open window mapping was employed. During pre-excitation, color-coded 3D mapping was analyzed to assess the electrical activity. Notably, the color crowding was observed near the His bundle, indicating a critical region of interest. A line of block was confirmed across other regions, but the leak was specifically identified at the His bundle location. Based on these findings, the non-coronary cusp of the Valsalva was targeted for ablation. Radiofrequency (RF) lesions were delivered precisely at the level of the non-coronary cups, successfully terminating the tachycardia.

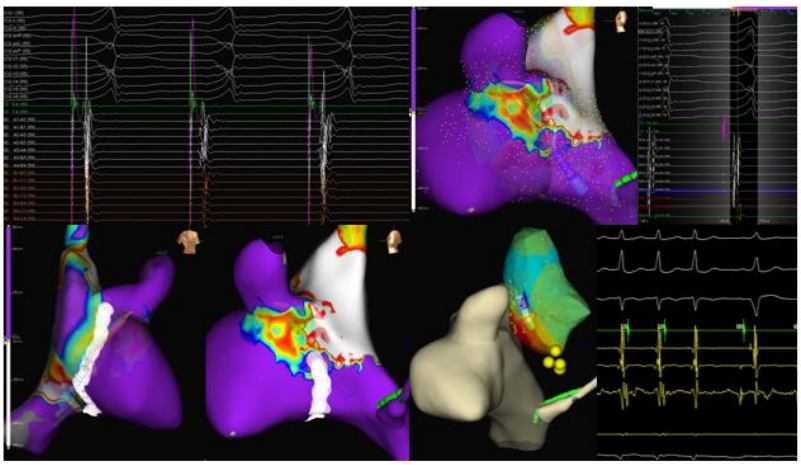

Fig (4): Intracardiac EGM and open window mapping demonstrating line of block and leak in the HIS region revealing Para-Hisian accessory pathway

Case 4: Left anterolateral accessory pathway (Figure 5)

A 32-year-old female, case of WPW syndrome, with pre-excitation suggestive of left anterolateral accessory pathway presented with recurrent episodes of palpitation and documented narrow complex tachycardia. During EP study, an open-window mapping technique was employed which confirmed the presence of a left anterolateral AP at 2'o'clock position of mitral annulus. RF ablation was performed at the same location, which lead to disappearance of pre-excitation and lack of inducibility of tachy-arrhythmia.

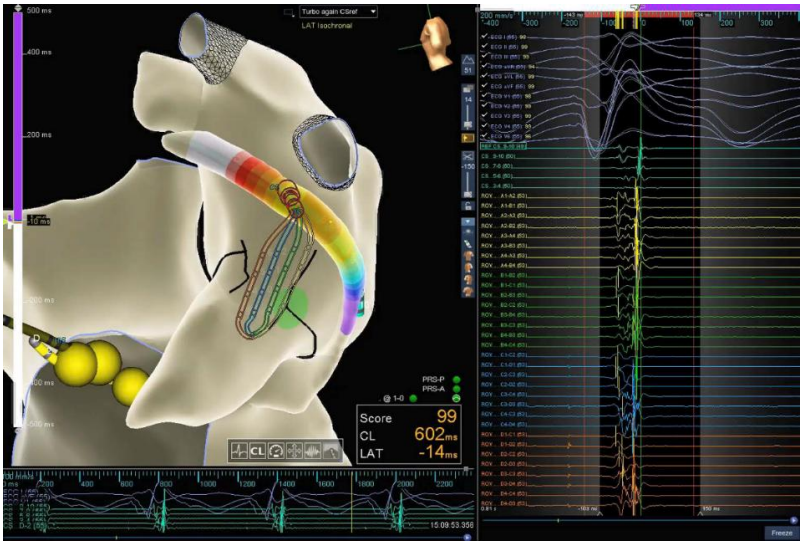

Fig (5): Intracardiac EGM and open window mapping demonstrating left anterolateral accessory pathway

Case 5: Left posteroseptal accessory pathway (Figure 6)

A 41-year-old male a case of left posteroseptal accessory pathway mediated orhodromic AVRT with a failed ablation attempt outside by conventional EP study and RFA, was taken up for ablation with OWM. 3D anatomical map with open window technique confirmed the presence of a left posteroseptal AP at 8'o clock position of mitral annulus. Successful RF ablation was done with the help of deflectable Agillis 8.5 F sheath, which lead to disappearance of the pre-excitation and non-inducible tachycardia.

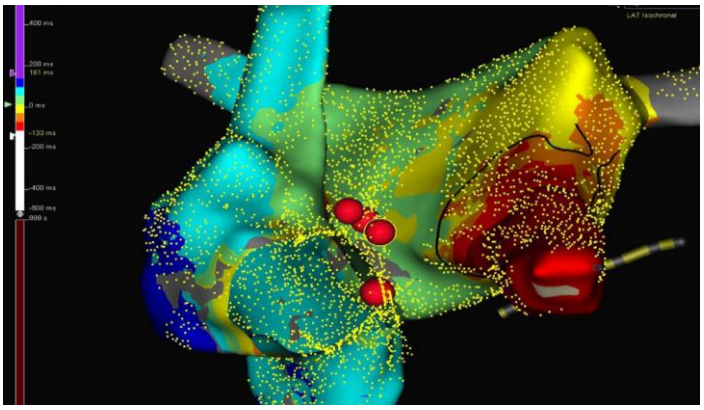

Fig (6): 3D anatomical presentation with open window mapping demonstrating RF lesions delivered at the 8'o clock position of mitral annulus for left posterior accessory pathway

Case 6: Ebstein's anomaly right anterolateral accessory pathway (Figure 7)

A clinical case of Ebstein's anomaly with a single accessory pathway was presented. During electrophysiology study, an open-window mapping technique was employed which confirmed the presence of the right anterolateral accessory pathway. Radiofrequency (RF) ablation was performed at the 5 o'clock position of the tricuspid annulus. The procedure was successful, with complete termination of the tachycardia observed post-ablation.

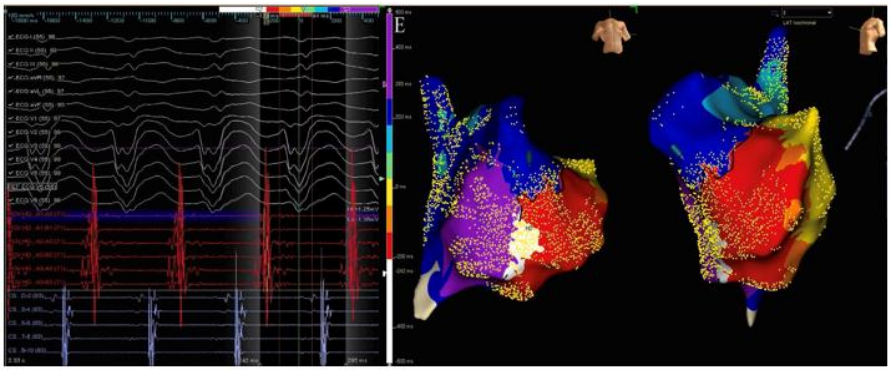

Fig (7): Intracardiac EGM and open window mapping demonstrating Right anteroseptal accessory pathway in Ebstein's anomaly

3. Discussion and Conclusion

In redo accessory pathway mapping, the differences between conventional electrophysiological (EP) mapping and open-window mapping are significant, particularly due to the complexities introduced by prior ablations. Conventional EP mapping, which uses a catheter with a limited number of electrodes for point-by-point mapping, may struggle to detect residual or new accessory pathways, especially in regions where scar tissue from the previous ablation has altered the heart's structure. Its lower resolution and slower, methodical approach can make it difficult to identify subtle pathways or changes in anatomy, often leading to missed areas for further intervention. In contrast, open-window mapping offers superior resolution and higher-density mapping, utilizing advanced 3D electroanatomical systems and real-time continuous data. This enables more precise identification of accessory pathways, including those hidden by scarring or altered by previous procedures. The speed and efficiency of open-window mapping also significantly reduce procedure time, allowing for faster localization and more accurate visualization of the pathways, thus improving the likelihood of successful ablation. As seen in our cases, open window mapping can also be employed for de-novo cases of AP- which can have better success rates and lesser chances of failure. Overall, open window mapping enhanced precision, faster workflow, and advanced technology make it a more effective tool in redo accessory pathway procedures compared to conventional EP mapping

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