Target potential for ablation in adenosine-sensitive atrial tachycardia originating from the vicinity of the atrioventricular node identified by the LUMIPOINT software

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Introduction

The RHYTHMIA (Boston Scientific, Marlborough, MA) mapping system was designed to provide automated mapping with ultra-high resolution. The LUMIPOINT software is used to identify the arrhythmia circuit, including atrial tachycardia (AT) and ventricular tachycardia.[1,2]

Adenosine-sensitive AT, which originates from the vicinity of the atrioventricular node (AVN-AT), is characterized by reentry with a slow conduction zone (SCZ) composed of calcium channel–dependent tissues.[3] Catheter ablation targeting the earliest atrial activation site (EAAS) in the AVN-AT carries the potential risk of atrioventricular (AV) block. Yamabe and colleagues[4] demonstrated the efficacy of radiofrequency (RF) energy application at the entrance site of the SCZ indicated by the manifest entrainment technique in eliminating the tachycardia. However, the complete AT circuit has not been comprehensively explained, and no studies have reported successful ablation of AVN-AT using LUMIPOINT.

This case report presents the first AVN-AT case in which the exact exit site of the SCZ is identified by the LUMIPOINT software, providing the optimal ablation site of the AT.

KEY TEACHING POINTS

- In adenosine-sensitive atrial tachycardia, which originates from the vicinity of the atrioventricular node (AVN-AT), radiofrequency (RF) energy application at the entrance site of the slow conduction zone detected by entrainment pacing is considered a valuable approach. However, the exact location of the slow conduction zone remains unknown, and the optimally ablated site has yet to be determined.
- Integrating the LUMIPOINT software within the Rhythmia system (Boston Scientific) has enabled identifying the exit site of the slow conduction zone, which exhibits presystolic potentials. Successful AT elimination has been achieved through RF energy application at this identified exit site.
- Even if the entrainment pacing to detect the entrance site would be difficult, focusing on the energy delivery to the highlighted exit site identified by LUMIPOINT might eliminate the AVN-AT.

Case report

A 37-year-old woman with no previous history of heart disease presented with palpitation. Electrocardiography showed a regular, narrow QRS and long RP tachycardia. The first ablation procedure was conducted at a different hospital using the CARTO system (Biosense Webster, Inc, Irvine, CA). The 3D activation mapping showed a focal AT pattern with the EAAS close to the AV node. The AT was terminated by RF energy delivery near the AV node; however, tachycardia recurred shortly after the ablation. Four months later, the second ablation session was performed using the RHYTHMIA System. Electrode catheters were positioned in the high right atrium (HRA), right ventricle, and His bundle (HB). Supraventricular tachycardia (SVT) was easily induced by atrial burst pacing. The EAAS was recorded at the HB. An 8 mg bolus injection of adenosine 5′-triphosphate terminated the SVT without AV block. During the SVT, ventricular burst pacing revealed ventriculoatrial dissociation, and differential atrial pacing did not exhibit ventriculoatrial

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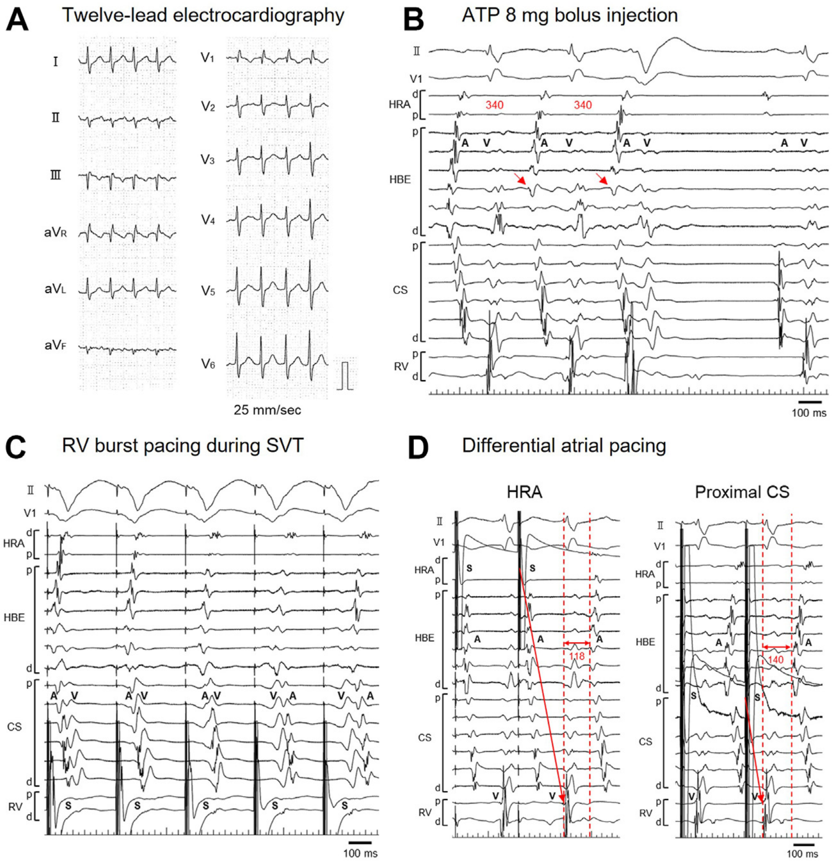

Figure 1 **A:** The 12-lead electrocardiography revealed a long RP, narrow QRS, and regular tachycardia with a heart rate of 161 beats/min. **B:** The tachycardia cycle length was 340 ms. The earliest atrial activation site was recorded at the His bundle electrogram (HBE) (*red arrow*) during the supraventricular tachycardia (SVT). After 8 mg bolus injection of adenosine 5′-triphosphate, a premature ventricular contraction occurred, and SVT was terminated without atrioventricular block. **C:** Burst pacing at the right ventricle (RV) during the tachycardia revealed ventriculoatrial dissociation. **D:** The difference in the postpacing ventriculoatrial interval between the high right atrium (HRA) and proximal CS entrainment pacing was 22 ms > 14 ms, indicating that the SVT was atrial tachycardia. ABL = ablation catheter; ATP = adenosine 5-triphosphate; d = distal; EAAS = earliest atrial activation site; p = proximal; S = stimulation.

linking (Figure 1). Thus, the SVT was diagnosed as AVN-AT. Entrainment pacing was performed during the AT in various sites of the right atrium, with a pacing cycle length of 30 ms shorter than the tachycardia cycle length. Entrainment pacing from the 6 o'clock position at the tricuspid annulus resulted in antidromic capture of the coronary sinus (CS) and HRA, whereas the EAAS was captured orthodromically. Pacing from the posterior of the HRA and proximal CS resulted in the antidromic capture of the EAAS, proximal CS, and HRA (Figure 2). These findings suggested that the entrance of the SCZ was lateral to the EAAS. The AT circuit around the tricuspid annulus was further evaluated by pacing from the 9 and 11 o'clock positions; however, the manifest entrainment could not be observed because pacing from these sites easily terminated the AT. The activation mapping using the Orion mapping catheter (Boston Scientific) revealed a centrifugal pattern, and the EAAS was located at the anterior portion of the tricuspid annulus, adjacent to the HB (Supplemental Video 1). However, LUMIPOINT at the upstroke in the SKYLINE highlighted a small region that activated earlier than the EAAS (Supplemental Video 2). This region was located approximately 8 mm away from the EAAS. Although RF energy application to the lateral site close to the highlighted region terminated the AT temporarily, it immediately recurred. The local electrogram recordings at the unsuccessful site of the ablation catheter (INTELLANAV MIFI OI; Boston Scientific) revealed less fractionated potentials. Thereafter, RF energy application at the highlighted region successfully eliminated the AT. Following this intervention, the AT could no longer be induced. The local electrogram recordings by the mapping catheter at the highlighted region displayed low amplitude and fractionated potentials. Similarly, the local electrograms recorded by the ablation catheter at the highlighted region revealed low amplitude and fractionated potential but did not precede the EAAS signal (Figure 3). During the 6-month follow-up, the patient was free from AT or any symptoms, without medications.

Discussion

In this case, LUMIPOINT software effectively determined the exit site of the SCZ and identified the optimal ablation site for AVN-AT.

In previous studies, the underlying mechanism of AVN-AT is reentry involving the SCZ within the circuit. Yamabe

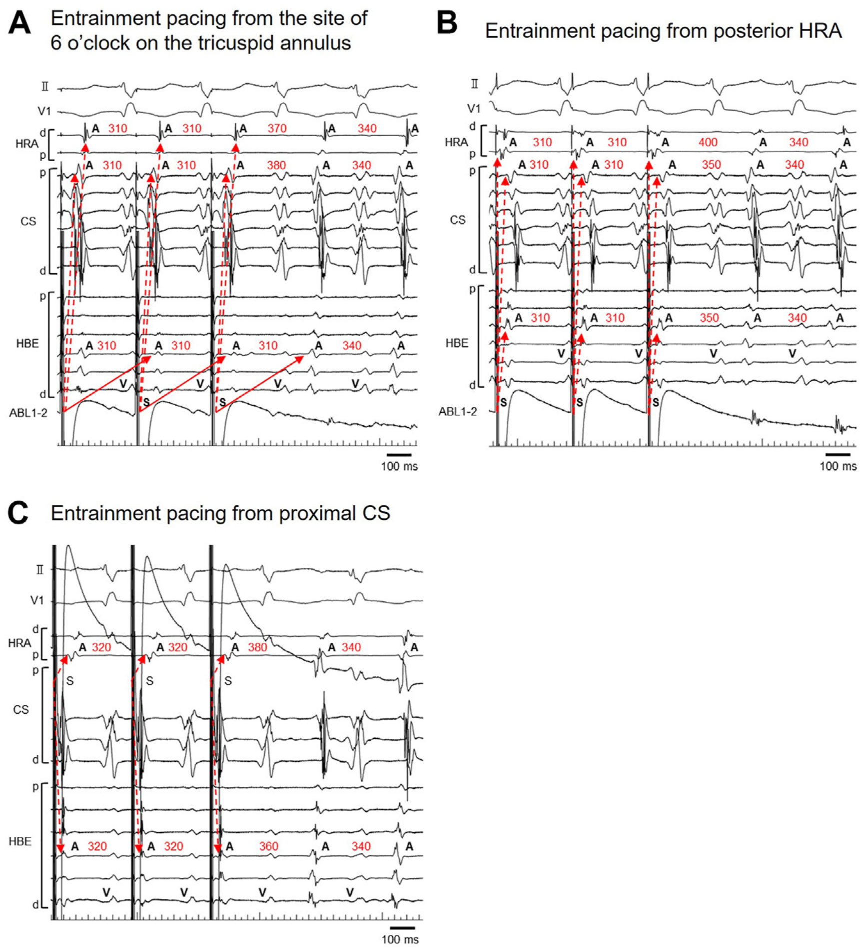

Figure 2 **A:** Entrainment pacing from the 6 o'clock position at the tricuspid annulus. The red solid and dotted arrows revealed orthodromic and antidromic atrial activations, respectively. The high right atrium (HRA) and coronary sinus (CS) were captured antidromically, whereas the earliest atrial activation site (EAAS) was captured orthodromically. **B, C:** Entrainment pacing from the posterior HRA and proximal CS. The HRA, CS, and EAAS were captured antidromically, indicating that the entrance of the slow conduction zone was located at the lateral site of the EAAS.

and colleagues[4] described that RF energy delivery at the entrance site of the SCZ, showing the slow potential, effectively terminated the tachycardia. The EAAS detected using a 3D mapping system (EnSite 3000 or EnSite NavX; St. Jude Medical, St. Paul, MN) has been considered the exit site of the tachycardia, whereas the entrance of the SCZ has been identified through the entrainment technique.[5] RF energy application was delivered to a site located 2 cm away from the pacing site in the direction where manifest entrainment was demonstrated. The ablation procedure targeting the entrance site of the SCZ was recognized as a safer and more effective therapeutic technique than ablation at the EAAS.[6] However, the precise location of the SCZ and entrance site in AVN-AT remains uncertain, posing a potential risk of AV block during ablation. Sakai and colleagues[7] presented a case of AVN-AT in which manifest entrainment could not be observed at various sites of the right atrium, except for the noncoronary aortic sinus (NCS).[7] Previous reports have demonstrated that NCS ablation was effective and safe. However, Barkagan and colleagues[8] reported a case of complete AV block requiring permanent pacemaker implantation following NCS ablation where the His potential was not recorded. These observations strongly suggest the importance of AVN-AT circuit identification to avoid AV block by ablation. In this case, we could identify the SCZ of the AVN-AT circuit using the LUMIPOINT software of the RHYTHMIA system and successfully ablated the AVN-AT without impairing AV conduction. Conventional local activation time maps often overlook fractionated electrograms and small prepotentials near the origins, leading to occasional mis-annotation of the EAAS. To address the limitations of conventional mapping systems, a novel software module, ie, LUMIPOINT, was developed.[2] This module highlights all activated areas regardless of local activation timing[1] and includes a 2-dimensional histogram feature (SKYLINE; Boston Scientific) that visualizes the relative surface area of activation. SKYLINE histogram patterns can differentiate AT mechanisms. Typical macroreentrant ATs do not exhibit a period of electrical silence during tachycardia. Meanwhile, focal or localized reentrant ATs often show a plateau period (>50 ms) followed by atrial activation.[2] In focal or localized reentrant ATs, the area corresponding to the upstroke in the SKYLINE histogram coincided with the successfully ablated site,[2] indicating the exit site of the AT. In this case,

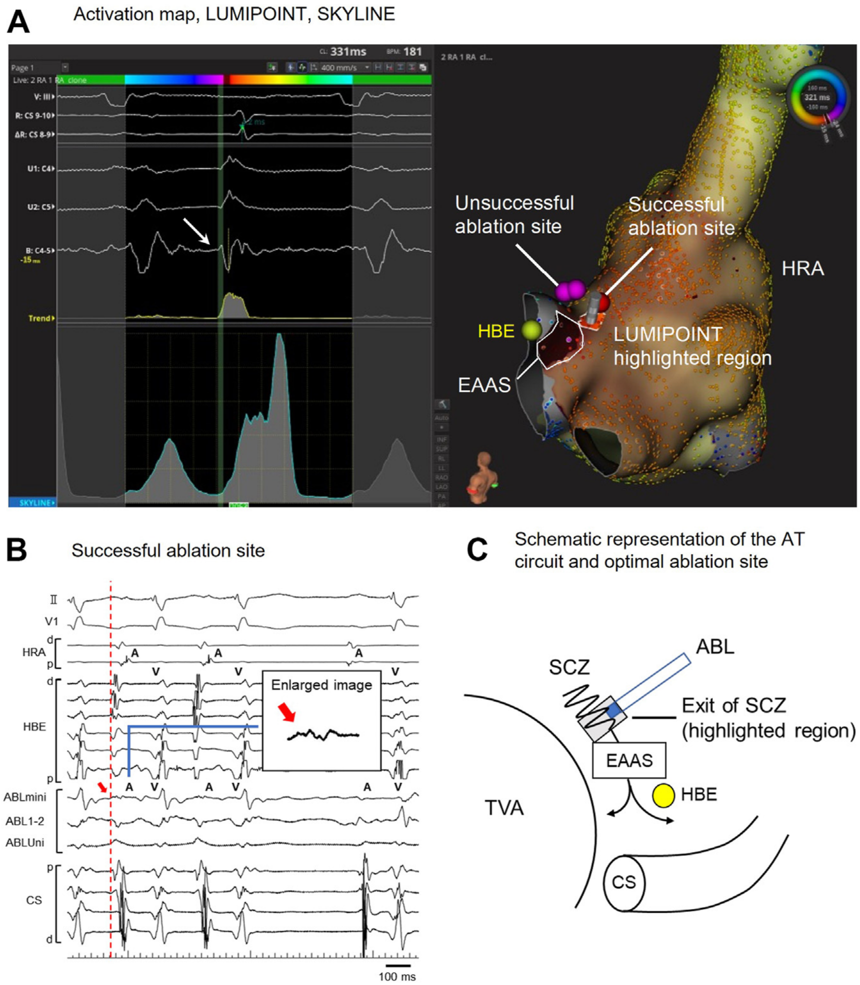

Figure 3 **A:** Preceding the upstroke in the SKYLINE histogram (*green shadow*), LUMIPOINT highlighted the region, located 8 mm away from the earliest atrial activation site (EAAS). The Virtual Roving Probe in the highlighted region shows the local electrogram (*white arrow*). The SKYLINE graph resembles a valley, but the initial small activation phase in SKYLINE is considered a plateau period. The second upstroke reflects the activation in the atrium, as the preceding phase is influenced by the far-field potential of the right ventricle, coinciding with the activation time of the QRS wave in the electrocardiogram and the activation spread at the tricuspid annulus (Supplemental Video 2). **B:** At the successful site, the electrogram of the ablation catheter revealed low amplitude and fractionated potential (*red arrow*). **C:** The atrial tachycardia (AT) propagated to the EAAS through the slow conduction zone (SCZ) at the lateral site of the EAAS. Radiofrequency energy application at the exit of the SCZ highlighted by LUMIPOINT successfully eliminated the AT. TVA = tricuspid valve annulus.

SKYLINE demonstrated the underlying AT mechanism was localized reentry and highlighted the successfully ablated site, located 8 mm away from the EAAS, showing a low amplitude and fractionated potential, consistent with a previous report.[9] These findings indicate that the effective ablation site for the AVN-AT is the exit site of the SCZ, as highlighted by the LUMIPOINT. The distance between the successfully ablated site and HB was also similar to previous findings. The local electrogram preceding that of the EAAS, indicating the presystolic potentials, was only detected by the Orion mapping catheter, whereas the ablation catheter's electrogram did not proceed. A previous study demonstrated that the atrial electrogram at the successfully ablated site appeared 15 ms later than the HB electrogram during AVN-AT.[9] This delay in electrogram detection is attributed to the low amplitude of the electrogram, which may not be accurately detected by the ablation catheter. Additionally, the annotation algorithm of LUMIPOINT software, which is unique and unlike any other 3D mapping systems, helps to identify the mechanism of this arrhythmia.

In the present case, LUMIPOINT using the Orion mapping catheter accurately identified the exit site of the SCZ, which activated earlier than the EAAS. Even if the entrainment pacing to detect the entrance site would be difficult, energy delivery to the exit site, as highlighted by LUMIPOINT, can effectively eliminate the AT. LUMIPOINT also provides information on the distance between the HB and the optimally ablated site. Compared with conventional methods, RF ablation using LUMIPOINT may potentially reduce the risk of AV node injury.

Conclusion

In this case, we used the LUMIPOINT and SKYLINE histogram of the RHYTHMIA system to investigate the underlying circuitry of AVN-AT. LUMIPOINT accurately determined the precise exit site of the SCZ, and the RF energy application at this region successfully eliminated the AT. Previous studies have identified the EAAS in the conventional 3-dimensional mapping system as the exit site of tachycardia, and RF energy delivery at the entrance site proves effective and safe. However, in this case, LUMIPOINT identified the "concealed" exit site. Energy delivery to the highlighted exit site indicated by LUMIPOINT may effectively eliminate AVN-AT.

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Appendix

Supplementary Data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2023.12.009.

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