Fast-slow Atrioventricular Nodal Reentrant Tachycardia Incorporating Superior and Inferolateral Left Atrial Slow Pathways

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Abstract

A 70-year-old man revealed a rare type of atrioventricular nodal reentrant tachycardia (AVNRT) involving distinct retrograde pathways, Superior Slow Pathway (SSP) and Inferolateral Left Atrial Slow Pathway (ILA-SP). Radiofrequency ablation was successfully performed on the non-coronary cusp and in the left atrium, respectively, to eliminate the tachycardias. Due to the anomalous electrical conduction patterns, careful diagnosis and ablation strategies were necessary to avoid the risk of atrioventricular block. These findings underscore the diversity and complexity of AVNRT and highlight the importance of tailored therapeutic approaches.

Introduction

Atrioventricular (AV) nodal (AVN) reentrant tachycardia (AVNRT) is electrophysiologically classified into three forms according to the antegrade and retrograde limbs; slow-fast, fast-slow, and slow-slow forms¹. Furthermore, several anatomical variants of the slow pathway (SP) such as rightward and leftward extensions^{2,3}, superior SP (SSP) and inferolateral left atrial (LA) SP (ILA-SP), have been reported despite the unique fast pathway (FP)^{1,4,5}. The earliest atrial activation (EAA) depends on the SP variant during the fast-slow AVNRT, which requires careful interpretation of the electrocardiogram to differentiate it from orthodromic reciprocating tachycardia (ORT) or atrial tachycardia (AT)⁶. We report a rare case of fast-slow AVNRTs with SP variants such as an SSP and ILA-SP.

Case report

A 70-year-old man with a history of hypertension was referred to our hospital for catheter ablation of a narrow QRS tachycardia. After obtaining informed consent, an electrophysiological study was performed. Atrial extrastimuli delineated a smooth AV decremental conduction curve. Ventricular extrastimuli also delineated a smooth ventriculoatrial (VA) decremental conduction curve with the earliest activation mainly seen in the His bundle (HB) region (Figure 1A), but occasionally in the distal coronary sinus (CS) (Suppl. Figure 1). A clinical supraventricular tachycardia (SVT1) with a tachycardia cycle length (TCL) of 390 ms and His-atrial (HA) interval of 180 ms was induced without an atrio-His (AH) jump by decreasing the coupling interval of the atrial extrastimuli. The earliest atrial activation was in the HB region and it preceded the EAA in the CS by 15 msec. Ventricular overdrive pacing showed VA dissociation (Figure 1B), excluding ORT with any accessory pathways. Differential atrial overdrive pacing from the proximal CS and lateral right atrium showed the presence of VA linking, which was diagnostic of AVNRT excluding AT (Figure C-1 and C-2). A 3D activation map of the right atrium showed that the EAA was in the HB region, suggestive of fast-slow AVNRT with an SSP as the retrograde limb. A radiofrequency (RF) application targeting the antegrade

slow pathway region up to the level of the CS roof failed to terminate the tachycardia. The ablation catheter was advanced to the non-coronary cusp (NCC) to avoid the risk of atrioventricular block. An RF application at the site with the atrial potential preceding that in the HB region by 12ms successfully rendered SVT1 noninducible (Figure 2B and C).

After a successful ablation of SVT1, SVT2 with a TCL of 390-400 and HA interval of 180 ms (same as SVT1) was induced. The earliest atrial activation was observed in the distal CS. Ventricular overdrive pacing showed VA dissociation (Figure 3B), excluding a diagnosis of ORT. Further, repeated RV overdrive pacing successfully entrained the atrium exhibiting a V-A-V response and the post-pacing interval minus the tachycardia cycle length (PPI-TCL) of 301ms (>115ms) (Figure 3C), indicated AVNRT. A bolus injection of adenosine-triphosphate (ATP) with a dose of 10 mg terminated this tachycardia without atrial activation, suggesting ATP sensitivity in a retrograde limb of SVT2 (Figure 3D). The AH interval during the SVT2 was almost the same as in SVT1, suggesting that the antegrade limb of the SVT2 was the fast pathway. These findings diagnosed SVT2 as a fast-slow AVNRT using an ILA-SP. A couple of the RF applications at the earliest atrial site within the CS failed to terminate the SVT2. An RF application in the LA where the local atrial potential preceded the CS potential by 20 ms (Figure 2F) rendered the SVT2 non-inducible, and which a junctional rhythm was observed during the RF application (Suppl. Fig 2).

Discussion

In this case, we found the two distinct retrograde atrial activations during AVNRTs of which the earliest site was in the HB region (Figure 1A) or the inferior lateral mitral annulus (Figure 3B and Suppl. Figure 1). SVT1 was diagnosed as a fast-slow AVNRT using the fast pathway as an antegrade limb and the SSP as a retrograde limb. Fast-slow AVNRT using an SSP is known to usually have a short AH interval, but in this case, since the AH and HA intervals during the tachycardia were nearly identical, a typical long RP pattern was not observed. Kaneko et al. have reported that not all cases of AVNRT via an SSP necessarily exhibit a short AH and long RP pattern, suggesting that there may be inter-individual diversity in the electrocardiographic appearance probably due to a balance between the antegrade and retrograde conductivities during the tachycardia ^{7,8}. They also reported that a double atrial response characterized by two types of retrograde conduction near the superior region of the AV node⁴ is recognized in some cases, but it was not observed in this case. We found several important findings of SVT1 such as atrial inducibility of the tachycardia without a jump in the AH interval, the EAA around the superior AV node, and no effect of ablation on the rightward inferior extension. According to those findings, we considered the fast pathway as an antegrade conductive pathway and the SP as the retrograde pathway before the first application of the RF delivery. Moreover, the fact that ventricular overdrive pacing during the tachycardia exhibited VA dissociation excluded the involvement of the accessory pathway and a concealed node-ventricular Mahaim fiber for the establishment of the tachycardia. Kaneko, et al. reported that VA dissociation during ventricular entrainment pacing of fast-slow AVNRT using an SSP, although not specific, was commonly observed due to block at the lower common pathway⁴. This phenomenon observed in this case, was also consistent with this type of AVNRT. Finally, differential atrial overdrive pacing excluded the AT for a diagnosis of the tachycardia. In terms of catheter ablation, since the EAA site during retrograde conduction via the SSP was close to the HB region, ablation of the SSP from the right atrium had a risk of AV node injury. A previous report noted that ablation from the NCC would be safe for the SSP ablation without the risk of AN node damage⁴. Ablation of the SVT1 was finally successful from the NCC without AV node injury.

The diagnosis of SVT2 as AVNRT was also made by ruling out the presence of an accessory pathway and atrial tachycardia during an electrophysiological study repeated after the ablation of the SPP. Interestingly, serial ventricular pacing during SVT2 could entrain the tachycardia, but also exhibited VA dissociation in some cases. This difference may have at least in part depended on a temporal change in the autonomic tone or blood concentration of isoproterenol that modified the conductivities of the lower common pathway. Alternately, the conductivities of the lower common pathway might become altered depending on the type of AV nodal circuit. The earliest activation site during SVT2 was observed at the mitral valve annulus in the LA, suggesting the ILA-SP as a retrograde limb of fast-slow AVNRT. Moreover, the development of

junctional rhythm observed during the RF application with an atrial breakthrough to the earliest activation site of SVT2, followed by termination of SVT2 may have also suggested the presence of the ILA-SP along the mitral annulus in the LA ^{1,9} that might have formed from AV nodal cell tissue¹⁰. A trans-septal approach to the LA might be better in patients with difficulty in terminating a tachycardia by ablating from the CS⁵.

Considering these results of the electrophysiologic studies and ablation, the retrograde conductivities of the ILA-SP were present before the ablation of the SSP. During SVT1, retrograde conduction via the ILA-SP was not manifested probably because the retrograde penetration into the ILA-SP encountered an antergrade wavefront into the ILA-SP due to a slightly longer VA conduction time of the ILA-SP than the that of the SSP. As a result, we could mainly observe retrograde conduction via the SSP before the NCC ablation (Suppl. Fig 3). Collectively, this is, to the best of our knowledge, the first report showing the involvement of the ILA-SP as a bystander pathway during fast-slow AVNRT using an SSP.

Conclusion

We experienced a rare case of two types of fast-slow AVNRT using an SSP and ILA-SP, respectively. Ablation in the NCC or LA would be needed for the unusual location of retrograde SPs.

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Figure legends

Figure 1 Electrophysiological observations of SVT1

A : Manifestation of retrograde conduction via the superior slow pathway (indicated by dot arrow) from a right ventricular (RV) apical extrastimulus with an S1-S2 coupling interval of 360 ms after basic overdrive pacing simultaneously from the coronary sinus (CS) and RV with an S1-S1 cycle length of 750 ms. Please note the earliest site of atrial activation (A2) during retrograde conduction over the superior slow pathway and S2-A2 interval measured as 410 ms in the His bundle recordings.

B: RV overdrive pacing with an S-S cycle length of 380 ms during SVT1, demonstrating VA dissociation, evidenced by no perturbation of the atrial cycles keeping with a cycle length of 390 ms during ventricular pacing.

C: Differential entrainment pacing at an S-S cycle length of 350 ms from the proximal CS (C-1) and low lateral right atrium (LLRA) (C-2). Please note that the VA interval immediately after the last stimulus during either pacing is measured as 115 ms.

CS p and CS d = the proximal and distal coronary sinus; His p and His d = the proximal and distal recordings of His bundle.

Figure 2 Successful ablation of SVT1 and SVT2

Electroanatomical activation mapping of SVT1 (**A**) and SVT2 (**D**), fluoroscopic views in the left anterior oblique view showing the position of the catheters including the ablation catheter (indicated by unfilled arrows) at the successful ablation site of SVT1 (**B**) and SVT2 (**D**), and intracardiac electrograms at the successful ablation site of SVT1 (**C**) and SVT2 (**E**).

Ao = aorta; LA = left atrium. Other abbreviations as figure 1.

Figure 3 Electrophysiological observations of SVT2

A : Intracardiac electrograms during the SVT2, with the atrial, His bundle, and ventricular deflections labeled as A, H, and V, respectively, on the distal His bundle recording (His d).

 \mathbf{B} : RV overdrive pacing with an S-S cycle length of 390 ms during SVT2, demonstrating VA dissociation, evidenced by no perturbation of the atrial cycles keeping with a cycle length of 400 ms during ventricular pacing.

 \mathbf{C} : Successful ventricular entrainment with an S-S cycle length of 380 ms, capturing the atria via the slow pathway (indicated by dot arrows), followed by reinitiation of the tachycardia with an initial V-A-V response. Please note the post-pacing interval is measured as 610 ms.

D : Termination of the tachycardia with a bolus injection of ATP with an end of the ventricular activation.

Other abbreviations are as in Figure 1.

Supplemental Figure 1Electrophysiological observations during ventricular pacing.

Manifestation of retrograde conduction via the ILA-SSP (indicated by dot arrow) during a right ventricular (RV) apical extrastimulus with an S1-S2 coupling interval of 340 ms after basic overdrive pacing simultaneously from the coronary sinus (CS) and RV with an S1-S1 cycle length of 750 ms. Please note the earliest site of the atrial activation (A2) during retrograde conduction was over the ILA-SSP and the S2-A2 interval was measured as 440 ms in the distal CS.

Supplemental Figure 2 Electrophysiological observations during ablation of SVT2

Junctional rhythm appeared during ablation of SVT2







Figure 2

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