Atrioventricular nodal reentrant tachycardia (AVNRT) is the most common regular supraventricular tachycardia. Slow pathway (SP) modification has evolved as the first-line treatment,1,2 with acute success rates of 95% to 98%. A sensitive sign for success of the procedure is observation of accelerated junctional rhythm (JR) during ablation.3 The serious complication of AV block (AVB) can occur, and affects ≈1% of patients during or after catheter ablation procedures.2,4 Some studies have demonstrated that loss of VA conduction during radiofrequency application predicts impending AVB during ablation.5,6 From this illustrative series of cases assembled from 4 large tertiary care centers during a period of 3 years, we analyze some possible reasons for occurrence of AVB, and suggest methods to prevent this complication during SP modification procedures.

Editor’s Perspective see p 745

Case 1
A 58-year-old woman with a history of paroxysmal supraventricular tachycardia was refractory to medical therapy and referred for ablation. The baseline AH and HV intervals were 80 and 50 ms, respectively. Atrial pacing at 600 ms demonstrated fast pathway conduction and jump to SP conduction with a single echo beat (Figure 1A, left). A narrow QRS tachycardia with the same retrograde conduction sequence was induced during isoproterenol infusion, by atrial programmed stimulation (Figure 1A, right), which was diagnosed as AVNRT with cycle length (CL) of 380 ms, AH of 280 ms, HV of 50 ms, and VA of 50 ms. No further pacing maneuvers were performed during tachycardia and SP modification was performed guided by fluoroscopy with a power setting of 30 W, temperature 60°C and total duration of 35 s. During radiofrequency delivery, JR with 1:1 retrograde conduction was observed during radiofrequency application with a CL between 500 and 600 ms, and 4 beats of sinus rhythm with relatively normal PR interval (Figure 1B). Complete AVB occurred following 1 beat of prolonged PR interval after terminating radiofrequency. Programmed ventricular stimulation (S1S2, 500/320 ms) showed nondecremental retrograde conduction with a short conduction time and similar retrograde atrial activation compared with tachycardia suggestive that a concealed septal accessory pathway was present (Figure 1C). The patient had implantation of a pacemaker 7 days after the ablation procedure without recovery of AV nodal conduction.

Case 2
A 65-year-old man with a history of paroxysmal supraventricular tachycardia was referred for a catheter ablation procedure. During the procedure, baseline intervals AH and HV were 85 and 52 ms, respectively. The anterograde effective refractory period of the fast pathway and SP was 600/320 ms and 600/280 ms, respectively. Atrial programmed stimulation induced narrow QRS tachycardia with CL of 290 ms, AH of 245 ms, HV of 45 ms, and VA of 0 ms, which was diagnosed as typical AVNRT (Figure 2A). SP modification was performed with a combined anatomic and electrogram mapping approach with power setting 30 W, temperature 60°C and total duration of 30 s. During ablation, JR with a CL of 480 to 500 ms was noted with 1:1 retrograde conduction followed by many ectopic atrial beats with relatively longer AV interval (Figure 2B). A slight change of QRS morphology was observed beginning at the fifth beat (Figure 2B). Complete AV block was noted after termination of radiofrequency application. Three wide QRS complex beats with relatively longer AV duration were observed at the end of radiofrequency application, followed by complete AVB (Figure 2C). The patient underwent permanent pacemaker implantation after the ablation procedure as there was no recovery of AV conduction.

Case 3
A 66-year-old man with a history of paroxysmal supraventricular tachycardia which was refractory to medical therapy presented for catheter ablation. During the procedure, the baseline AH and HV intervals were 142 and 56 ms (Figure 3A left), respectively. The VA interval was 150 ms at a drive CL of 600 ms and decremental VA conduction was observed with programmed ventricular stimulation with earliest atrial activation.
at the His region (Figure 3A, right). SVT with CL of 365 ms, AH of 265 ms, HV of 55 ms, and VA of 45 ms was induced by programmed atrial stimulation (CL, 500/300 ms) with similar atrial activation seen during ventricular stimulation (Figure 3B). The diagnosis of AVNRT was confirmed by ventricular pacing maneuvers. Radiofrequency application was applied at the posterior septal region with power setting 50 W, temperature 60°C and duration of 37 s. A large atrial potential was recorded on the ablation electrode before and during radiofrequency application and radiofrequency was terminated after complete AVB was observed (Figure 3C). A single premature atrial beat was noted just before AVB was observed and was correlated with a sudden rise in impedance and a faint audible pop (Figure 3C and D). The patient underwent pacemaker implantation the following day after no meaningful recovery of conduction was observed.

**Case 4**

A 58-year-old woman with a history of paroxysmal supraventricular tachycardia underwent an ablation procedure. During the procedure, the baseline AH and HV intervals were 90 and 40 ms (Figure 4A), respectively. Decremental VA conduction was observed during programmed ventricular stimulation with the earliest atrial activation at the His channel and antegrade refractory periods of the fast pathway and SP of 500/310 ms and 500/230 ms, respectively. Atrial programmed stimulation induced narrow QRS tachycardia with a CL of 320 ms, AH of 280 ms, HV of 40 ms, and VA of 0 ms, which was diagnosed as slow/fast AVNRT (Figure 4B). Radiofrequency application was applied at the posterior septal region with a power setting of 30 W, temperature 55°C for a total of 9 s. During radiofrequency delivery, an initial small atrial potential was noted to change to a larger atrial potential. Radiofrequency was terminated immediately within 4 beats where the larger potential was noted with total duration of 1.9 s. The changes in signal corresponded to 3 premature atrial beats and 1 junctional beat before radiofrequency termination. Immediately after termination of radiofrequency, high degree AVB was noted (Figure 4C and 4D). AVN conduction quickly recovered with no AH interval prolongation and the same tachycardia was subsequently reinduced. Successful SP modification was then performed again with radiofrequency delivery.

**Discussion**

AVNRT is the most common regular supraventricular tachycardia. Catheter-based SP modification has become a first line
treatment strategy with high success rates. Successful ablation can be judged during ablation by the occurrence of JR. Nikoo et al.7 illustrated 7 different patterns of JR during SP modification. They found that development of slow JR had higher success rates than fast JR. The mean CL of junctional ectopy was longer (464.6±167.5 versus 263.4±250.2; \( P < 0.01 \)) with effective versus ineffective radiofrequency applications. However, the serious complication of A VB may occur during SP modification, and affects ≈1% to 2.3% of patients during these procedures.2,4 Retrograde conduction block during JR or development of rapid JR are significant predictors of A VB in patients undergoing SP ablation. Previous studies have suggested several strategies to avoid A VB including transient discontinuation of energy delivery with the development of JR, and multiple repeat ablations with progressively longer durations ≤30 s.5 Another method proposed by Liberman et al.9 argued that rapid atrial pacing during ablation could be used to ensure intact anterograde conduction. However, JR that is slightly faster than the pacing CL may be difficult to identify in this setting and retrograde conduction cannot be assessed during JR. The termination of radiofrequency application can be delayed by a few seconds and may result in anterograde A VB.

In this case series, there was either slow JR with retrograde conduction or no JR before complete A VB occurred, findings that have not been described in previous studies.

In case 1, a concealed AP with AVRT was misdiagnosed as slow/fast AVNRT because the VA interval was <70 ms and no further diagnostic maneuvers were performed during tachycardia. Retrograde conduction was present with JR during SP modification. This, however, may have provided false assurance that retrograde fast AV nodal conduction was intact as conduction was through an accessory tract.

In case 2, complete AVB occurred after radiofrequency energy application was terminated. JR was observed during radiofrequency application with 1:1 retrograde conduction, after a few beats of ectopic atrial activity with prolonged AV duration and wide QRS complexes at the end of radiofrequency application. A slight change of QRS morphology at the fifth beat was noted, as this should not occur during SP modification. PVCs could be coupled with atrial potentials mimicking 1:1 retrograde or antegrade conduction. The careful observation of QRS morphology, continued fluoroscopic monitoring, or the use of three-dimensional
(3D) electroanatomic mapping could prevent this type of complication.

In case 3, complete AVB occurred suddenly during SP modification without JR, which is unusual. A premature atrial ectopic beat was noted and correlated with a sudden brief change of impedance and audible sound at the end of radiofrequency application indicating the occurrence of a pop injury. An audible pop may occur occasionally during SP modification with relatively higher power output and may lead to transient AVB. Common sites of SP modification are located at the posterior septal tricuspid annulus, and generally have lower electrode temperatures (<50°C during 30–40 W radiofrequency applications). If higher power outputs with temperature control mode are used during SP modification, in general full power delivery will be achieved as it will be difficult to reach temperatures of 55°C to 60°C in this region because of high blood flow and movement of the catheter. This higher power delivery may be too aggressive and unnecessary to ablate the thinner structure at the AV nodal region. This patient had a relatively long AH interval and left bundle branch block indicating disease of the conduction system, which may independently increase the risk of AVB during SP modification. The large atrial potential before and during radiofrequency application indicated a coronary sinus (CS) site. In a small percentage of cases of AVNRT, it may be necessary to ablate within the CS with larger atrial potentials, however, ablation at the roof of the proximal CS carries a high risk of AV nodal block during radiofrequency application. Unfortunately, the location of the ablation electrode was not recorded during this case so the exact location cannot be confirmed.

In case 4, the ablation electrode moved to the proximal CS during radiofrequency application with recorded large atrial potential and superiorly directed surface P-wave morphology for 2 s before radiofrequency termination. AVB can occur
quickly in a few seconds of radiofrequency application without proceeding JR if the radiofrequency application is directed at the roof of the CS, in which the compact AV node is located.

Learning from this case series, we would suggest that the following steps are important for prevention of AVB during SP modification procedures: (1) avoidance of radiofrequency application within the proximal CS, especially at the roof of the CS with relatively large atrial potentials; (2) termination of radiofrequency application with the onset of fast JR or retrograde conduction block during JR; (3) termination of radiofrequency application with any changes in amplitude of atrial and ventricular potentials in the ablation electrode, or any change in QRS morphology; (4) to perform diagnostic maneuvers for any SVT to confirm the diagnosis, even in cases with short VA conduction; (5) limit higher power output during radiofrequency application in this region; (6) awareness of higher risk patients with advanced age, and a relatively long AH interval; (7) continued fluoroscopic monitoring or the use of 3D mapping systems during radiofrequency application for detecting catheter movement; and (8) the use of a proper speed of electrophysiological recording (100 mm/s) during radiofrequency application for identifying changes of atrial and ventricular potentials at the ablation electrode.

**Disclosures**
None.

**References**


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Atrioventricular Block During Slow Pathway Ablation: Entirely Preventable?
Hongwu Chen, Michael Shehata, Wei Ma, Jing Xu, Jianing Cao, Eugenio Cingolani, Charles Swerdlow, Minglong Chen, Sumeet S. Chugh and Xunzhang Wang

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