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SPOTLIGHT

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A case of biatrial tachycardia involving the intercaval bundle with assumed dual loop reentry

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Circumferential pulmonary vein (PV) isolation is the accepted interventional therapy for atrial fibrillation. However, PV isolation with entrance and exit block may not be possible if epicardial connections, referred to as an intercaval bundle,[1] exist between the right atrium (RA) and right PV (RPV). According to several authors, the presence of an intercaval bundle necessitates PV carina ablation.[2,3] There are only a few reports describing atypical atrial flutter related to an intercaval bundle.[4] Here, we present a case of biatrial macroreentrant tachycardia involving epicardial connections between the RA and RPV.

The patient was a 71-year-old man with a history of stable coronary artery disease with percutaneous coronary intervention. He had undergone radiofrequency ablation for persistent atrial fibrillation and typical atrial flutter. During the procedure, PV isolation and cavotricuspid isthmus lines were applied. RPV isolation required carina ablation. Five months later, he was referred for ablation of recurrent atrial flutter, and a second ablation procedure was performed. The surface electrocardiogram showed positive P waves in leads II, III, aVF, and V1-6 (Figure 1A). The tachycardia cycle length was 295 ms. Left atrial three-dimensional electroanatomical mapping (Rhythmia, Boston Scientific, Marlborough, MA, USA) showed RPV reconnection. Inside the RPV isolation line, two different earliest activation sites were identified (Figure 1B–D; Video S1). At these sites, entrainment mapping showed differences in post-pacing interval and a tachycardia cycle length of 0 to 30 ms; however, entrainment mapping at the anterior wall and roof of the left atrium and inside the right superior PV showed differences in post-pacing interval and a tachycardia cycle length greater than 30 ms (Figure 1D). Furthermore, entrainment mapping showed concealed entrainment at the two earliest sites (Figure 2A,B) but manifest entrainment at the other three sites (anterior wall and roof of the left atrium, inside the right superior PV).

Right atrial three-dimensional electroanatomical mapping revealed a centrifugal pattern at the earliest site at the posterior wall of the superior vena cava (Figure 1D; Video S2). At this site, entrainment mapping showed differences in post-pacing interval and a tachycardia cycle length of 0 to 30 ms, and concealed entrainment (Figure 2C).

Pacing from the two earliest sites of the RPV had a long stimulus-to-surface P wave, but entrainment from the posterior superior vena cava had a short stimulus-to-surface P wave, indicating that pacing from the RPV did not capture the superior vena cava. Furthermore, entrainment pacing from point (b) showed orthodromic capture with concealed entrainment in the sites close to point (c) (the earliest site of RA) (Figure 2B). Entrainment pacing from point (d) showed orthodromic capture with manifest entrainment in RA, although the position of Orion was unstable. Findings indicated that the slow conduction zone was between the RPV, that is, (b), (d), and the posterior wall of the RA (c). We assumed a figure-of-eight reentry circuit (Figure 3A,B; Video S3) and aimed to ablate the common pathway between the two earliest sites inside the RPV isolation line. Radiofrequency (RF) energy was delivered at the carina with an IntellaNav MiFi OI ablation catheter (Boston Scientific) at 40 W for 25 to 50 s, with a target of 15-ohm impedance drops (Figure 3C). At the second point of energization, the proximal site of the ablation catheter recorded fragmented potentials and the tachycardia stopped within 4 s of applying RF energy (Figure 3D). When the tachycardia had stopped, in the distal RF catheter we recorded triple potentials (Figure 3D), which might indicate far-field RA and RPV potentials through superior and inferior RA-RPV connections. After completing the carina line, we verified

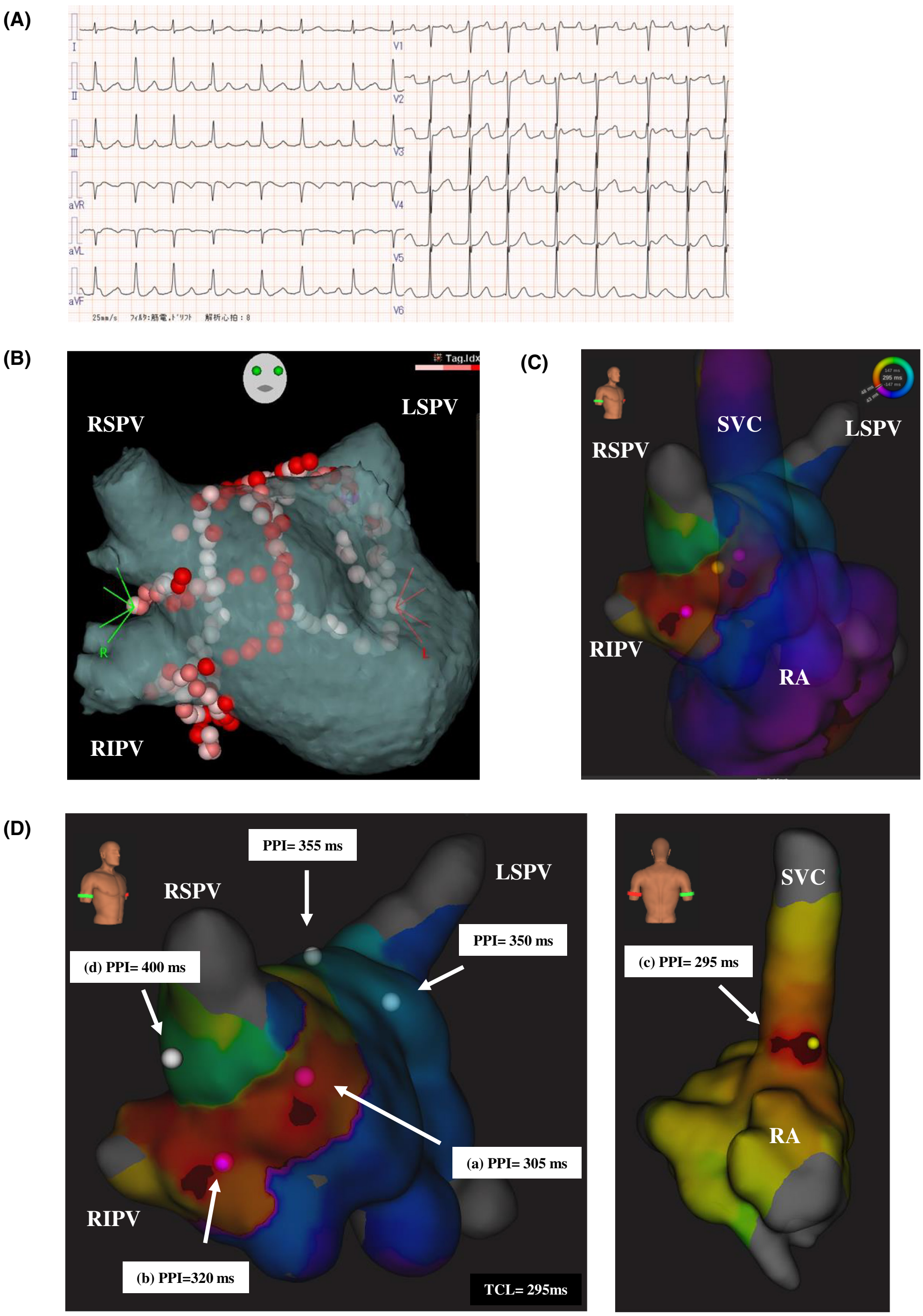


FIGURE 1 Surface electrocardiogram findings, radiofrequency application sites in the first procedure, and earliest activation sites in atrial flutter. (A) Twelve-lead electrocardiogram showed atrial flutter with positive P waves in leads II, III, aVF, and V1-6; negative P waves in lead aVL and aVR; and almost isoelectric P waves in lead I. (B) In the first procedure, pulmonary vein isolation was performed. To isolate the right pulmonary vein, carina ablation was needed. (C) Activation map of the left and right atrium. (D) Activation map of the left atrium showed reconnection of the right pulmonary vein. The earliest sites were at the septum inside the isolation line. Activation map of the RA revealed a centrifugal pattern in the earliest site at the posterior wall of the SVC. The figure shows measurements of the differences between the PPI and TCL at the earliest sites of both atria, the roof, the anterior wall of the left atrium and inside the RSPV. LSPV, left superior pulmonary vein; PPI, post-pacing interval; RA, right atrium; RIPV, right inferior pulmonary vein; RSPV, right superior pulmonary vein; SVC, superior vena cava; TCL, tachycardia cycle length.

the inducibility of atrial arrhythmias by burst pacing. Roof-dependent atrial tachycardia was induced and showed reconnection of the RPV via the gap in the posterior left atrium (Video S4). We performed RF ablation at the posterior gap of the PV isolation line and created a roof line (Figure 3E). No events have occurred in the 28 months since the procedure.

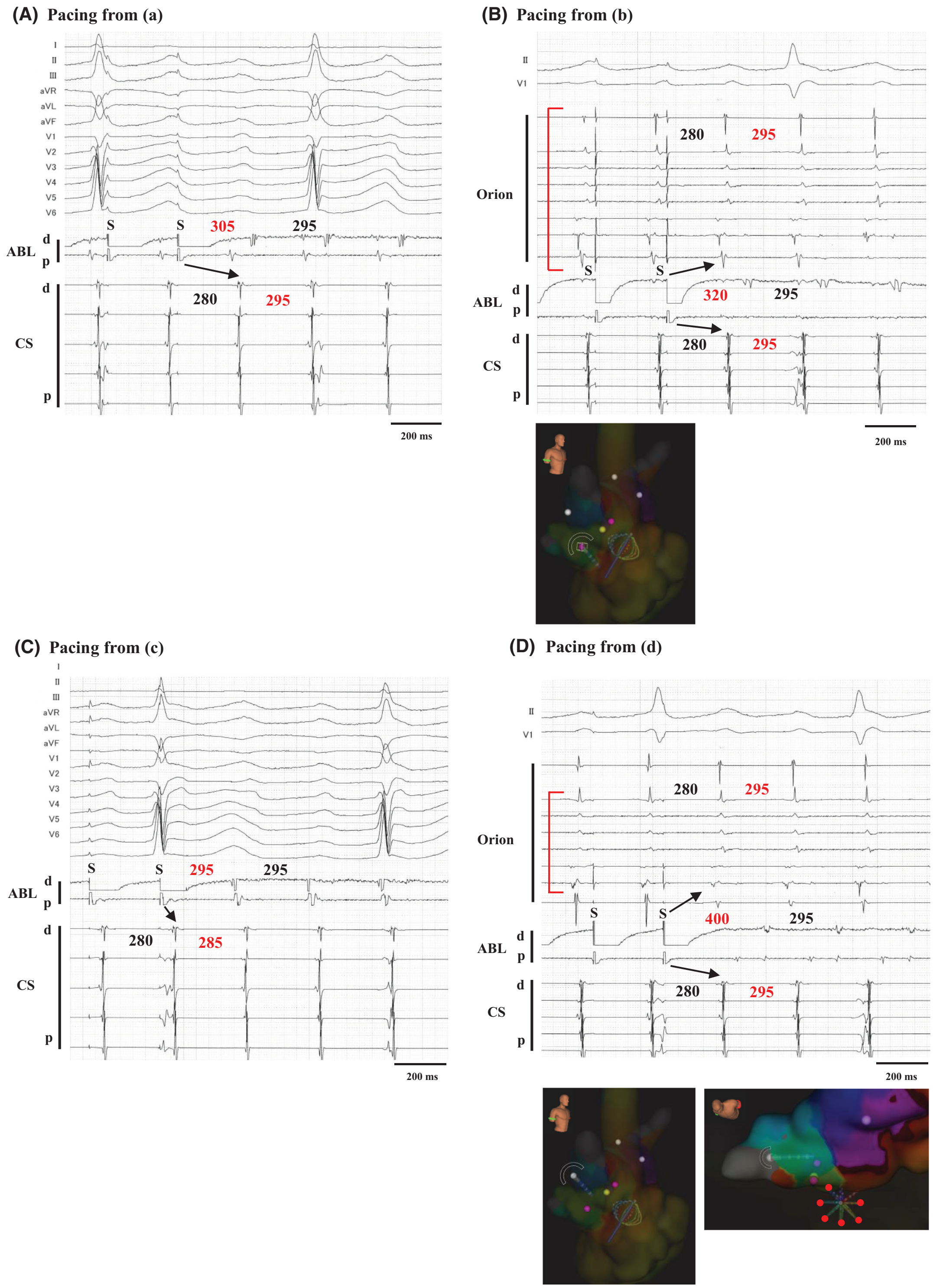
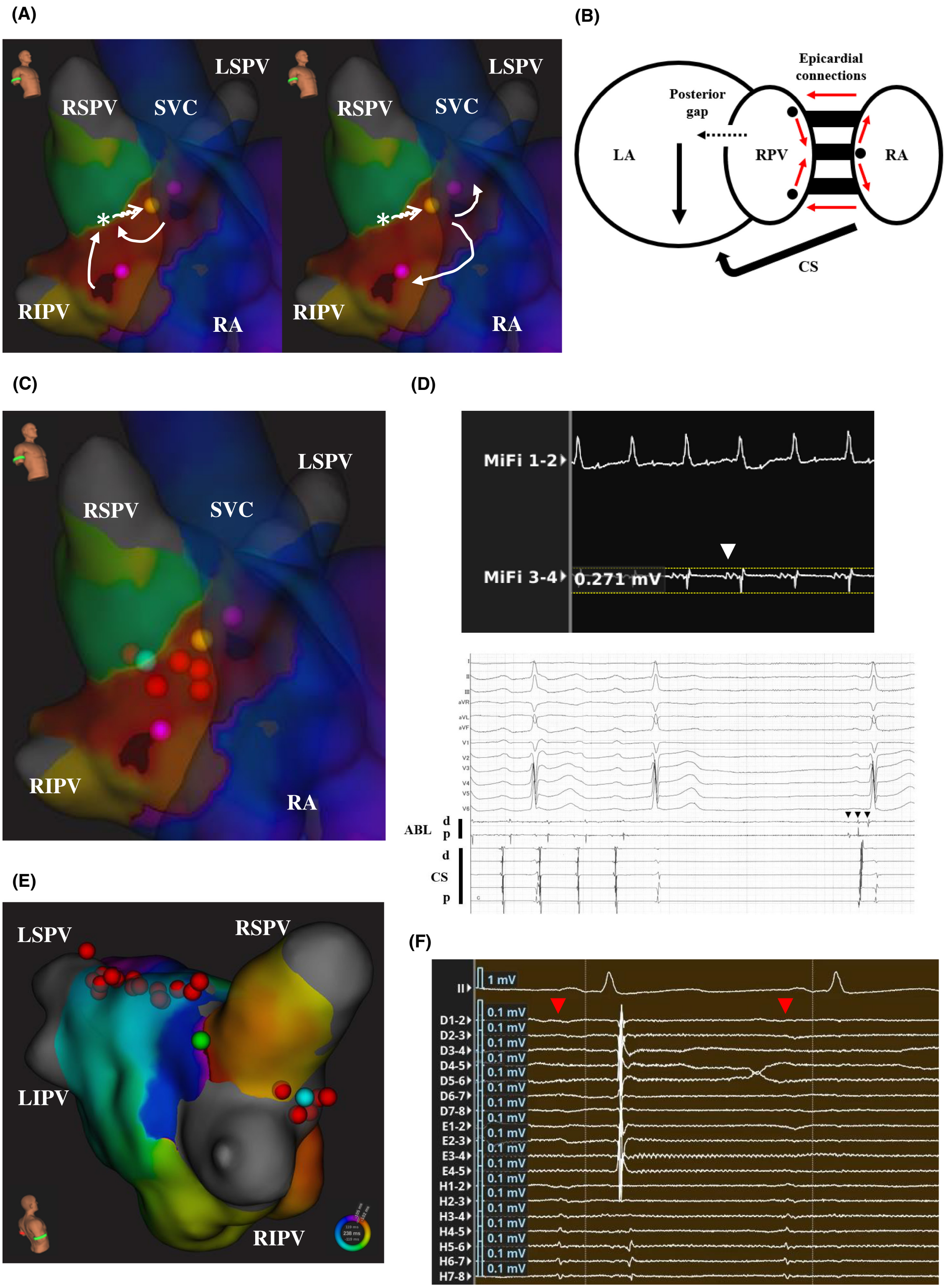


FIGURE 2 Entrainment mapping at points (a–d). (A) Entrainment mapping at one of the earliest sites inside the pulmonary vein isolation line (a) showed concealed entrainment and differences in post-pacing interval and a tachycardia cycle length of 10 ms. Pacing showed orthodromic capture in the proximal and distal portions of the CS. (B) Entrainment mapping at one of the earliest sites inside the pulmonary vein isolation line (b) showed concealed entrainment and differences in post-pacing interval and a tachycardia cycle length of 25 ms. Pacing showed orthodromic capture in the sites close to the earliest site of RA and the proximal and distal portions of the CS. The position of Orion was shown in the lower panel. (C) Entrainment mapping at the earliest site of the RA (c) showed concealed entrainment and differences in post-pacing interval and a tachycardia cycle length of 0 ms. Pacing showed antidromic capture in the CS. (D) Entrainment mapping at point (d) inside the right superior pulmonary vein showed differences in post-pacing interval and a tachycardia cycle length of 105 ms. Pacing showed manifest entrainment and orthodromic capture in the sites close to the earliest site of RA (point (c)), which were marked with red dots in the lower panel. ABL, ablation catheter; CS, coronary sinus; d, distal; p, proximal; RA, right atrium.



Atypical atrial tachycardias are common iatrogenic arrhythmias after atrial fibrillation ablation. We reported a case of biatrial tachycardia involving epicardial connections between the RPV and RA. These epicardial connections were named the intercaval bundle.[1] Several authors reported that this bundle can cause reconnection of the PVs,[2,3] and Patel et al. mentioned uncommon atrial tachycardias related to the intercaval bundle.[4] We assume that in the current case, the atypical atrial tachycardia circuit was as shown in Figure 3A,B. Entrainment mapping from points (b) and (d) showed orthodromic capture in RA, which indicated the slow conduction zone was between RPV and RA.[5]

FIGURE 3 Presumed reentry circuit and radiofrequency (RF) treatment. (A) The presumed circuit was a figure-of-eight reentry through the epicardial connections. The purple and yellow dots indicate the earliest sites of the RPV and RA, respectively. The asterisk site is the presumed entrance site. (B) Schematic diagram of the assumed circuit of the tachycardia. Red arrowheads indicate the presumed circuit of the tachycardia. Black dots represent the earliest activation sites of the RPV and RA. Black arrowheads demonstrate the propagated excitation in the left and right atrium. (C) RF ablation was applied at the carina between the two earliest sites inside the isolation line. The red dots represent the RF application sites, and the light blue dot represents the tachycardia termination site (presumably the entrance site of the common pathway). (D) RF energy was delivered at the carina at a power of 40 W for 25 to 50 s with a target of 15-ohm impedance drops, and the tachycardia stopped within 4 s of RF application at the second point of energization (light blue dot in (C)). The white arrowhead in the upper panel shows the fragmented potentials in the three-dimensional electroanatomical mapping system (Rhythmia); these potentials represent the slow conduction zone when ablating the light blue dot. The black arrowheads in the lower panel show the triple potentials in the ABL when the tachycardia was terminated. (E) After the tachycardia was terminated, roof-dependent atrial tachycardia was induced by burst pacing and showed reconnection of the RPV via the posterior gap in the left atrium. A roof line was created, and the RPV was isolated by RF application at the green dot. ABL, ablation catheter; CS, coronary sinus; d, distal; LIPV, left inferior pulmonary vein; LSPV, left superior pulmonary vein; p, proximal; RA, right atrium; RIPV, right inferior pulmonary vein; RPV, right pulmonary vein; RSPV, right superior pulmonary vein; SVC, superior vena cava. (F) When RPV was isolated due to ablating the posterior gap, far-field RA potentials were shown as red arrows in the three-dimensional electroanatomical mapping system (Rhythmia). These potentials were the same phase as the first of the triple potentials proceeding P wave in (D).

Indeed when terminating tachycardia, the proximal site of the ablation catheter recorded fragmented potentials, suggesting a slow conduction zone (Figure 3D). Additionally, triple potentials just after terminating the tachycardia showed far-field RA and RPV potentials. The first potential was far-field RA potential because it was also represented in Figure 3F. Therefore, the second and third potentials demonstrated the connections (superior and inferior) from RA to RPV during sinus rhythm. These findings were consistent with the assumed circuit involving three epicardial connections.

There are three possible reasons why this uncommon atrial tachycardia occurred. First, the intercaval bundle was included inside the very wide circumferential RPV isolation line. Second, the intercaval bundle may have had regional tissue heterogeneities, such as an accessory pathway of Wolff-Parkinson-White syndrome; such heterogeneities may cause unidirectional conduction.[3] Last, the first RF ablation at the carina caused conduction delays in the surrounding tissues.

In our patient, the carina ablation was effective in ablating the entrance site of the common pathway (i.e., the RPV and RA connection). In contrast, Patel et al. ablated the earliest activation site of RA to interrupt the intercaval bundle and achieve PV isolation.[4] Epicardial connections between the RPV and RA are complicated.[1] Therefore, the RPV carina was the better target in this case because it injured the myocardium as a slow conduction zone.

Epicardial connections between the RPV and RA can cause uncommon atrial tachycardias. In the present case, special circumstances caused a biatrial tachycardia involving these epicardial connections.

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CONFLICT OF INTEREST STATEMENT

Authors declare no conflict of interests for this article.

DATA AVAILABILITY STATEMENT

The data that support the findings of this research are available from the corresponding author upon reasonable request.

DECLARATIONS

Approval of the research protocol: N/A. *Informed consent*: Patient consent for publication was obtained. *Registry and the registration no.*: N/A. *Animal studies*: N/A.

PATIENT CONSENT STATEMENT

The authors confirm that written consent for submission and publication of this case report, including the images and associated text, was obtained from the patient in line with Committee on Publication Ethics guidance.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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