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CASE SERIES
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Right coronary artery compromise following radiofrequency catheter ablation for supraventricular tachycardia: cases reports

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Background Coronary compromise is a serious potential complication following catheter ablation; however, procedural details in the literature are often lacking, preventing the identification of learning opportunities.

Case summary We report two cases of right coronary compromise following catheter ablation for symptomatic supraventricular tachycardia. After radiofrequency energy delivery at the coronary sinus ostium in both cases, inferior lead ST-elevation was observed. Diagnostic coronary angiography identified an occluded posterior left ventricular branch of the coronary artery, and optical coherence tomography demonstrated a high thrombus burden at this location. Electrocardiographic ST-segments settled with implantation of a drug-eluting stent.

Discussion Coronary compromise was likely secondary to energy delivery during catheter ablation. This case series highlights the need for electrophysiologist to understand coronary anatomy relative to anatomical landmarks, to anticipate the risk of vascular injury as physical distance from the site of ablation is likely important. Risk for coronary compromise, while a rare complication, needs to be discussed with patients during the consenting process. We also demonstrate the importance of an efficient multi-disciplinary team process for managing acute procedural complications.

Keywords Case report • Catheter ablation • Supraventricular tachycardia • Myocardial infarction • Coronary artery compromise

ESC curriculum 3.2 Acute coronary syndrome • 3.4 Coronary angiography • 5.1 Palpitations • 5.5 Supraventricular tachycardia • 7.4 Percutaneous cardiovascular post-procedure

Learning points

- Radiofrequency catheter ablation at the coronary sinus ostium is associated with injury to the posterior left descending coronary artery.
- Coronary injury may be associated with a high thrombotic burden and a need for coronary stenting to achieve normal arterial blood flow.
- Patients should be counselled about potential coronary complications during the consenting process for an ablation procedure.

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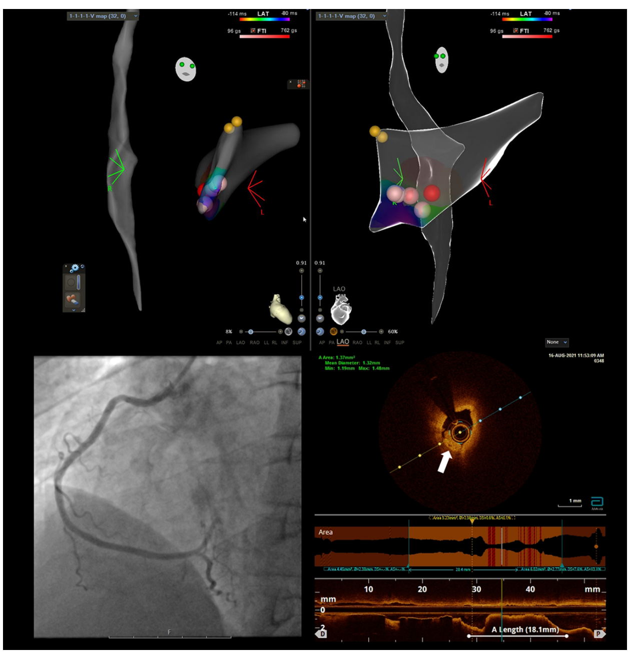
Introduction

Radiofrequency (RF) catheter ablation is an established treatment for supraventricular tachycardia (SVT).[1] Ablation-related coronary artery compromise is a rare but serious complication following catheter ablation. Data from retrospective studies suggest an incidence between 0.1% and 0.6%, with higher rates in patients with pre-existing structural heart disease.[2–4] However, the risk of coronary compromise is predominantly driven by the site of ablation, such as within the coronary sinus (CS) where the distance between the catheter and a major coronary artery branch is often smaller.[5] Additionally, while registries and studies have reported the frequency of this complication, procedural details are often lacking, which prevent the identification of learning opportunities to lessen their occurrence.

We report the cases of two patients who underwent RF catheter ablation with subsequent right coronary compromise requiring emergency revascularization.

Summary figure



- RF catheter ablation at the coronary sinus ostium is associated with compromise to the posterior left descending coronary artery.
- Coronary compromise may be associated with a high thrombotic burden and a need for coronary stenting to achieve normal arterial blood flow.
- Although rare, patients should be counselled about potential coronary complications during the consenting process for an ablation procedure.

Case summary

Patient 1

A 43-year-old Caucasian male attended an elective cardiac electrophysiology (EP) study and ablation. Three years previously, he had undergone ablation at the CS ostium for a right-sided posteroseptal accessory pathway. However, there was evidence of recovery of the pre-excitation on electrocardiogram (ECG) and palpitation symptoms. He had a background of bipolar affective disorder (treated with lithium 1.2 g once evening) with no cardiovascular risk factors and no other relevant medical history. Physical examination was unremarkable. His 12-lead resting ECG showed a short PR interval (100 ms), and widespread delta waves that transitioned from negative to positive between V1 and V2 were negative in lead III and aVF and positive in leads I, II, aVL (*Figure 1*).

The procedure was performed under general anaesthesia as per the patient's preference. The EP study identified non-decremental atrioventricular (AV) conduction with proximal to distal atrial activation on the CS catheter. Tachycardia was easily inducible, which made it not possible to determine the refractory period of the accessory pathway. The Biosense Webster CARTO3 three-dimensional (3D) mapping system was used, and the earliest ventricular signal that was 30 ms ahead of QRS onset was mapped to the tricuspid valve annulus at the mid-septal position. A Biosense Webster ThermoCool SmartTouch D-curve catheter with contact force sensing and irrigation was used to deliver ablation at this location (*Figure 2A*). Four brief energy applications had no effect on the pathway (*Figure 2B*). However, ablation at the anterior aspect of the CS lip [65 s; average (av) power, 37 W; av temperature, 37 °C; av force, 12 g; maximum impedance, 135 Ω] resulted in a loss of pre-excitation and split atrial and ventricular signals (*Figure 2C*). Repeating the EP study confirmed no anterograde or retrograde pathway conduction.

Ten minutes after ablation, with the patient still under general anaesthesia, inferior ST-segment elevation was observed on surface 12-lead ECG recording, in the absence of haemodynamic compromise and physical examination was unremarkable (*Figure 3*). A diagnostic coronary angiogram was promptly performed after a multi-disciplinary team discussion. This identified a patent left coronary artery system; however, there was a subtotal occlusion of the posterior left ventricular

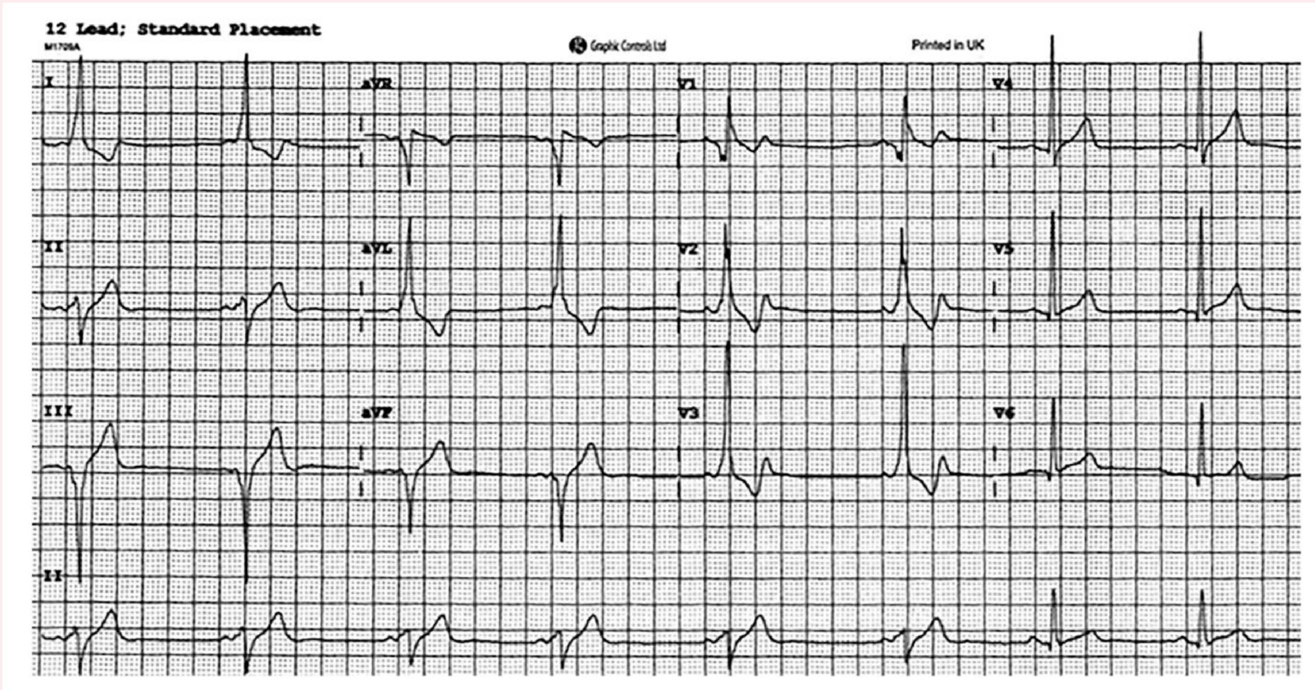


Figure 1 Resting 12 lead electrocardiogram pre-procedure (Patient 1). Twelve-lead resting electrocardiogram (standard lead placement, 25 mm/s) from a clinic appointment preceding the procedure. Intermittent pre-excitation is observed (lead II rhythm strip). Pre-excited beats show a short PR interval 80 ms and a delta wave. The delta wave transition point from a negative to positive deflection between V1 and V2, negative deflection in leads III and aVF, and positive in I and aVL is suggestive of a right posteroseptal accessory pathway. Pre-excitation is absent in the final two beats of the rhythm strip in lead II, with corresponding beats captured on leads V4–V6 showing a normal PR interval (160 ms) and no delta waves.

(PLV) artery branch and mild proximal disease of the right coronary artery (RCA) (*Figure 4A*; see Supplementary material online, *Video S1*). In the left anterior oblique projection, this was compatible with the location of the RF catheter in the CS. Optical coherence tomography (OCT) confirmed a high thrombus burden with a small lumen despite pre-dilatation with a 2 × 15 mm semi-compliant balloon (*Figure 4B*; see Supplementary material online, *Video S2*). Therefore, a 2.5 × 28 mm SYNERGY drug-eluting stent was inserted, restoring Thrombolysis in Myocardial Infarction (TIMI) score 3 flow with resolution of the ST elevation on ECG (*Figure 4*; see Supplementary material online, *Videos S3 and S4*).

The patient was discharged the following day on dual anti-platelet therapy (aspirin 75 mg once daily and prasugrel 10 mg once daily), with no further symptoms; however, his ECG did suggest recovery of the ablated accessory pathway. Echocardiography 2 months later identified a left ventricular ejection fraction of 50–55% with hypokinetic inferior and basal inferoseptal walls. One year later, he remains well with no chest pain or clinical signs of heart failure and continues on prasugrel 10 mg once daily and atorvastatin 20 mg once evening. Despite pre-excitation on his ECG, he has not had any recurrence of symptoms due to SVT suggesting the pathway has been modified. He is therefore being managed conservatively and followed up regularly in the clinic.

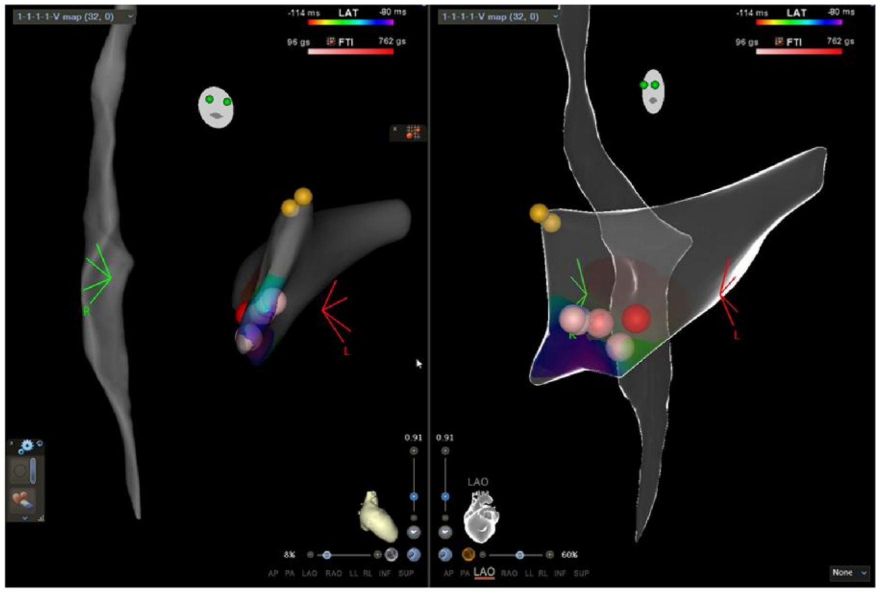
Patient 2

A 41-year-old Caucasian female attended for an elective atrial ectopic ablation under conscious sedation. She had a focal ectopic atrial tachycardia ablation 3 years previously with the location of energy delivery at the CS ostium. However, she subsequently developed a recurrence of symptoms (frequent palpitations) and was intolerant of medications including Flecainide. A Holter monitor identified a symptomatic long RP tachycardia with inverted P-waves suggesting an origin at the inferior aspect of the atria outside of the sinus node (*Figure 5A*). Frequent premature atrial ectopics were also observed (*Figure 5B*). She had no cardiovascular risk factors and no other relevant medical history. Physical examination was unremarkable and echocardiography confirmed a structurally normal heart.

EnSite Precision 3D mapping was used to delineate right atrial geometry and activation mapping (*Figure 6A*). The earliest activation of clinical ectopy was at the inferior margin of the CS ostium. Clusters of ablation at this location using a 4 mm irrigated catheter with contact force sensing, terminated the atrial ectopy (*Figure 6B*). A steerable sheath was not used, and large oscillation in contact force was observed due to cardiac and respiratory movements (*Figure 6C*).

Immediately after ablation, subtle (1 mm) inferior ST-segment elevation was noted with deep T-wave inversion in leads V1–V3 (*Figure 7*), and conduction intervals (PR and QRS) were unchanged. The patient denied any chest pain and remained haemodynamically stable, and physical examination was unremarkable. Diagnostic coronary angiogram identified unobstructed left coronary arteries; however, on imaging the RCA, the PLV branch was occluded (*Figure 8A*; see Supplementary material online, *Video S5*). Optical coherence tomography demonstrated smooth endothelium throughout; however, thrombus was present at the site of occlusion along with evidence

A



B

Ablation point		1	2	3	4	5
Time (s)		13	23	9	16	65
Avg Power (W)		30	30	29	30	37
Temp (°C)	Max	37.6	41.3	37.5	38.3	43.1
	Avg	34.1	36.9	35.2	32.5	31.7
Impedance (Ω)	Max	155	149	143	151	135
	Avg	33	28	14	37	33
Force (g)	Max	29	32	34	30	30
	Avg	9	14	12	14	12

C

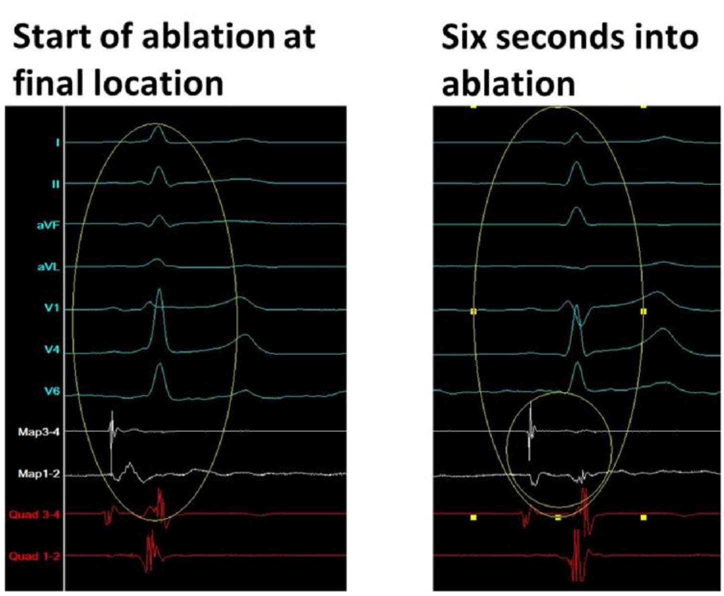


Figure 2 Ablation points and corresponding parameters (patient 1). (*A*) Images from the Biosense Webster CARTO 3 mapping system indicating the ablation points (round balls) in right and left anterior oblique views, in the left- and right-hand images, respectively. The final ablation point at the anterior aspect of the coronary sinus lip (larger spherical lesions) resulted in the loss of pre-excitation. (*B*) Ablation parameters for each point, with 5 being the final location when loss of pre-excitation was observed. (*C*) Comparison of the electrocardiogram signals at the start of ablation at the final location (left) and 6 s into ablation (right) when loss of the delta wave was observed with split atrial and ventricular signals (Map1-2). The surface ECG (I, II, aVF, aVL, V1, V4, and V6), ablation catheter (Map 1-2 and 3-4), and quadrapolar (Quad 1-2 and 3-4) catheter (placed in the coronary sinus) signals are shown in blue, white, and red colours respectively. Avg, average; g, grams; s, seconds; W, watts; Ω, ohms.

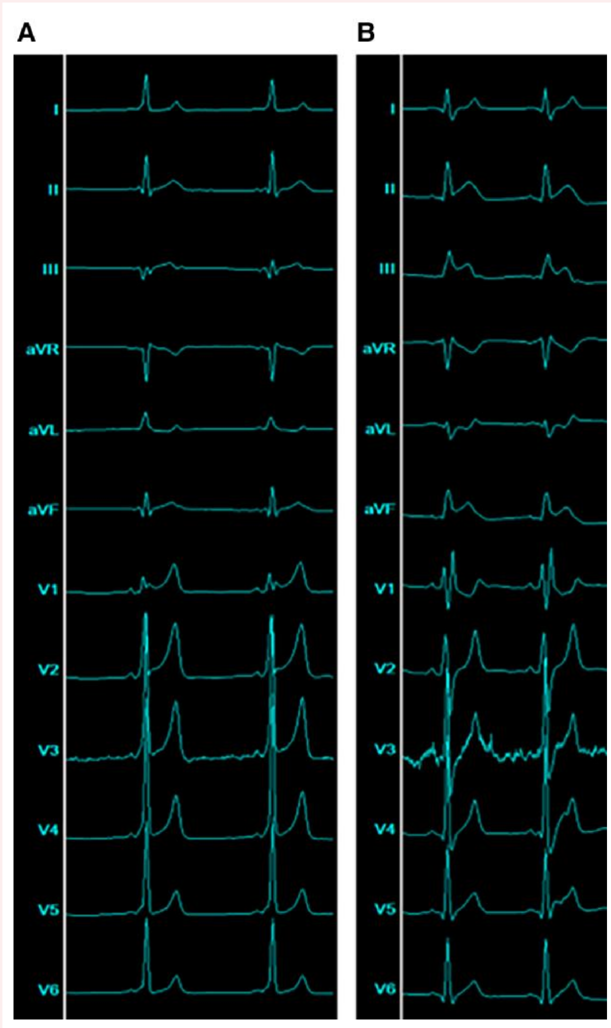


Figure 3 Electrocardiogram changes pre- and post-ablation (Patient 1). Baseline surface 12-lead resting electrocardiogram prior to ablation (*A*). There is a short PR interval and delta wave suggesting an accessory pathway; however, no ST-segment abnormalities. *B* demonstrates the absence of pre-excitation on the 12-lead surface electrocardiogram; however, there is acute ST-segment elevation in leads II, III, and aVF with reciprocal ST-depression in lead aVL, potentially indicating an acute inferior myocardial infarction affecting the right coronary artery territory.

for localized dissection. Serial balloon dilatation was unable to restore normal arterial flow, and therefore, a 2.5 × 18 mm Xience Pro stent was inserted (*Figure 8B*; see Supplementary material online, *Video S6*).

A serum troponin 16-h post-procedure was 656 ng/L. The patient was discharged 2 days later on dual anti-platelet therapy (aspirin 75 mg once daily and ticagrelor 90 mg twice daily) without symptoms, and an echocardiogram showed normal left ventricular systolic function and no regional wall motion abnormalities. One year later, she has had no recurrence of atrial tachycardia and remains on aspirin 75 mg once daily.

Discussion

We report two cases of right-sided RF ablation that led to coronary artery compromise requiring percutaneous coronary intervention. As transeptal and arterial puncture was not performed, the most likely explanation is compromise directly due to the energy applied during ablation.

Coronary artery compromise is a recognized but rare complication following RF catheter ablation. The physical distance between ablation site and the coronary artery appears to be important. Stavrakis *et al.*[5] report 50% (11/22) of patients had evidence of new vascular injury when ablation was performed within 2 mm of a coronary artery. However, none was observed when the site was greater than 5 mm. Histological evidence from a pig model identified endothelial disruption and smooth muscle cell necrosis when epicardial RF lesions (20 W, 20 s, 60 °C) were applied within 5 mm of an artery.[6] Ablation near or within the CS is therefore more likely to result in coronary artery compromise. The ostium and terminal aspect of the CS is in close proximity to an adipose-filled region containing a U-turn portion of the RCA known as the 'U-turn of James'.[7] Mao *et al.*[8] report in a study of 50 patients with computed tomographic (CT) angiography measurements; 42 had RCA dominance with the posterolateral ventricular branch 3.6 mm ± 1.9 (mean ± standard deviation) from the CS ostium. However, its course can run within 1.9 mm ± 1.3 of the body of the CS, indicating the potential for coronary artery compromise if ablation is performed within the CS. Imaging of the coronary arteries prior to ablation to establish proximity to ablation sites is unlikely to be recommended given the risks of CT and invasive angiography; however, our case series highlights the need for operators to have an understanding of coronary anatomy relative to anatomical landmarks to anticipate the risk of vascular injury. Care should be taken with energy delivery in these areas. A contact force sensing catheter should be used and catheter stability should be optimized, for example with the use of steerable sheaths where necessary, to ensure that there are no large fluctuations in the contact force applied.

It is of interest also that both patients in our series had previous uncomplicated ablation at the ostium of the CS. Radiofrequency ablation produces lasting coagulative tissue necrosis, and therefore, it is possible that prior ablation created a vulnerable state that subsequently increased the likelihood of compromise.[9] A formal study is warranted to investigate this. However, the size of tissue damage appears to correlate with the duration of energy application and the size of the catheter tip, indicating potential strategies to reduce the risk of subsequent arterial injury in close proximity.[9]

For both of our patients, we identified a high thrombus burden on OCT. In blood samples of 48 patients undergoing slow pathway ablation for AV nodal re-entrant tachycardia, increased von Willebrand factor levels (a marker of endothelial dysfunction) and measures of blood clotting activation were recorded when compared with pre-ablation values indicating a predisposition to thrombosis, which is well recognized following RF ablation.[10,11] Therefore, while physical distance is likely important for the risk of coronary artery compromise, this is further compounded by a pro-thrombotic state. The decision to proceed with stenting was made after limited improvement in luminal diameter despite serial balloon dilation in both cases. Recognition was made for the long-term need for anti-platelet therapy; however, this was balanced against the risk of potential lasting myocardial damage if arterial blood flow was not rapidly improved. There is limited robust clinical evidence in the literature regarding pro-thrombotic effects of right atrial cryo-ablation vs. RF ablation; however, an animal study suggests RF energy to be significantly more thrombogenic.[12] Cryo-ablation

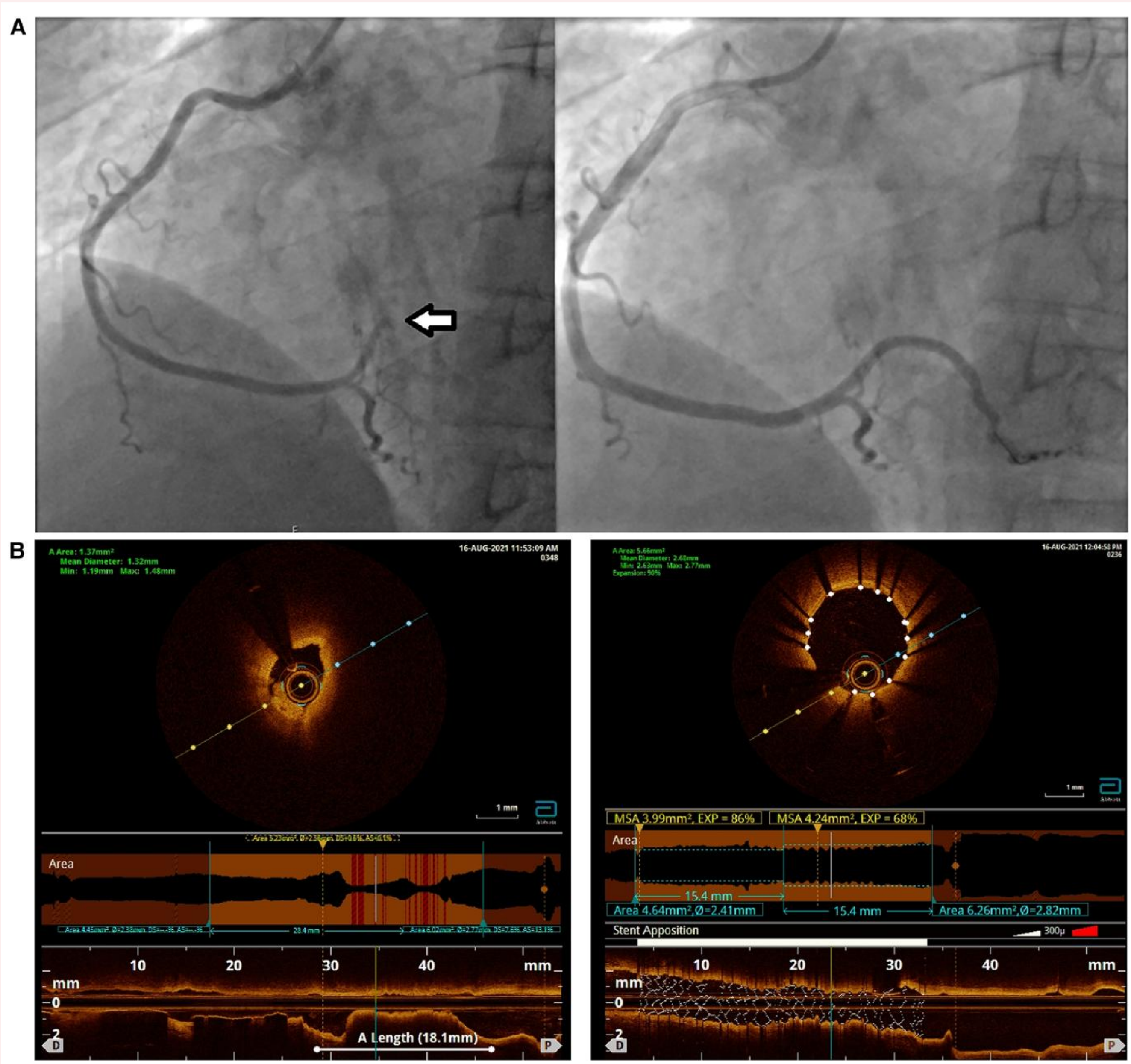


Figure 4 (*A*) Coronary angiography findings pre- and post-percutaneous coronary intervention (Patient 1). Coronary angiography identified a subtotal occlusion of the posterior left ventricular branch of the right coronary artery (left image, white arrow). Insertion of a drug-eluting stent restored flow in this vessel (right image), with resolution of accompanying electrocardiogram changes. See accompanying video clips of pre- and post-percutaneous coronary intervention findings. See also Supplementary material online, *Videos S1* and *S3* for pre- and post-percutaneous coronary intervention angiography. (*B*) Optical coherence tomography findings pre- and post-percutaneous coronary intervention (Patient 1). Left-hand panel: On optical coherence tomography, the cross-sectional image demonstrated a high thrombus burden (white arrows) with a small lumen with an area of 1.4 mm^2 despite pre-dilation. The area at the end of this stenosis was 6.0 mm^2. The location of the cross-sectional image is indicated by the thick white vertical lines on the two longitudinal images below that show this section corresponds with a segment with a reduction in arterial lumen diameter and can be used to estimate the size of stent required for implantation. The shadow caused by the guidewire is indicated by the white asterisk. Right-hand panel: optical coherence tomography post-percutaneous coronary intervention showed well-opposed stent struts (white arrows). See also Supplementary material online, *Videos S2* and *S4* for pre- and post-percutaneous coronary intervention optical coherence tomography.

may also be less likely to cause coronary artery compromise;[5] however, there is insufficient evidence to support a change in clinical practice.

As is common practice in our centre for right atrial ablation (excluding atrial flutter), the patient was neither anticoagulated nor heparinized during the ablation procedure. There is limited evidence to

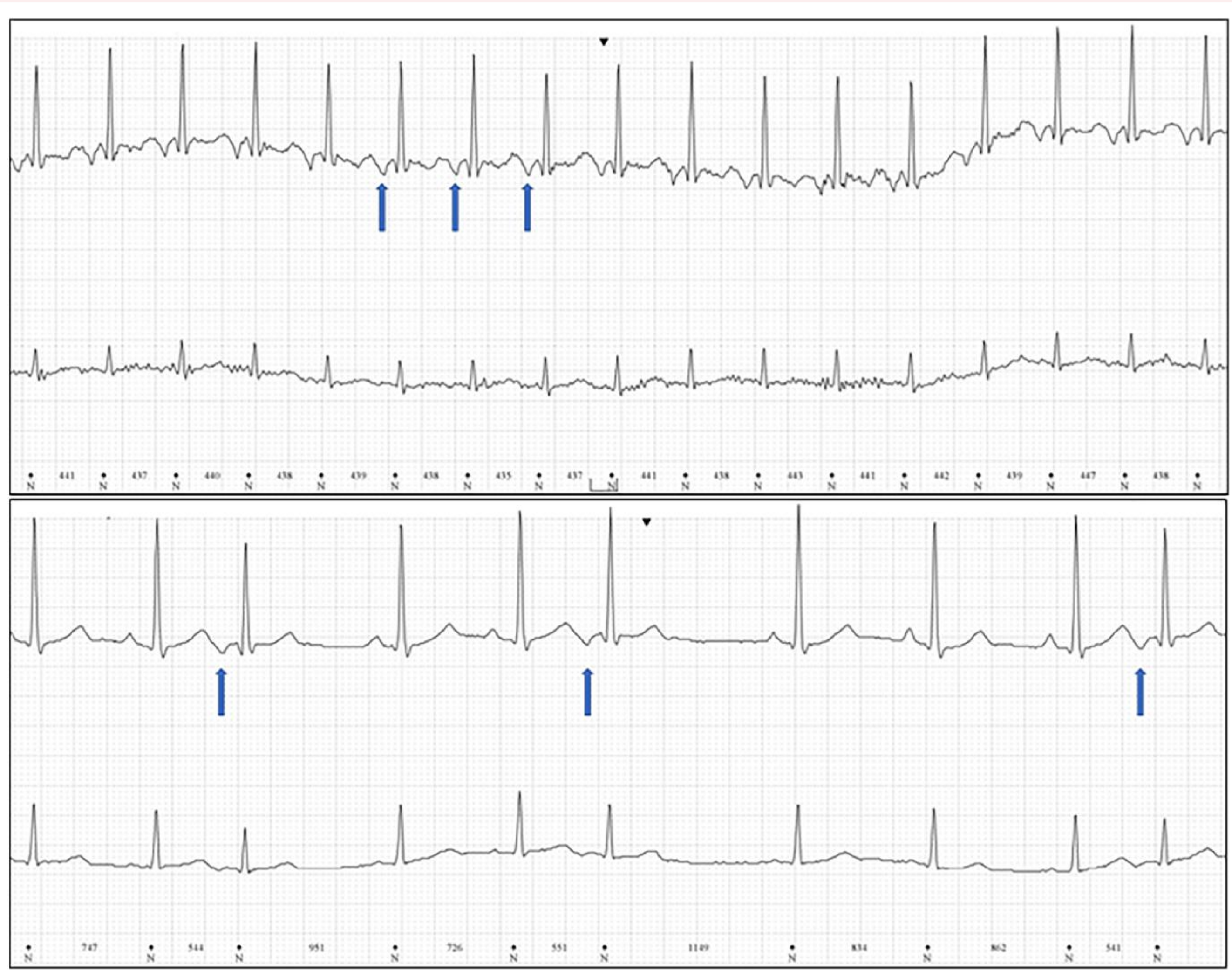
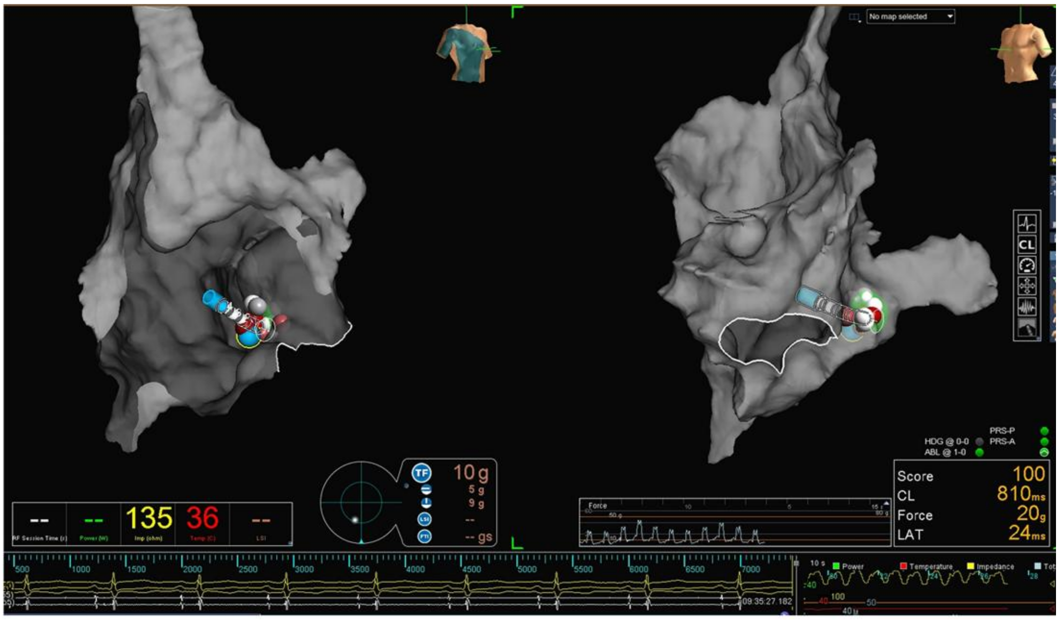


Figure 5 Long RP tachycardia and ectopy identified on Holter monitoring (Patient 2). Top panel: episodes of narrow complex tachycardia (average RR interval 440 ms) were captured on Holter monitoring. Inverted P-waves are present suggesting an origin at the inferior aspect of the atria outside of the sinus node (blue arrows). The distance between the onset of the QRS (marked by *n* and a small black upward arrow) and the next P-wave is long and therefore is a 'long RP' tachycardia. Bottom panel: Episodes of atrial ectopy were also identified with a similar P-wave morphology (blue arrows). Prior to undergoing the second ablation procedure, this ectopy correlated with symptoms.

support heparinization during these procedures. A systematic review suggested a reduction in risk for venous thromboembolism (deep vein thrombosis and pulmonary embolus) with concurrent heparin use; however, this was also associated with an increased risk for bleeding complications including femoral haematoma.[13] Therefore, current guidelines from the European Heart Rhythm Association do not suggest consideration only for heparinization and not a requirement, as they are recognized to be low thrombotic risk procedures.[14]

In our case series, we report ST-segment changes within 10 min of ablation, highlighting the need to carefully review the ECG before completing the procedure. As these procedures are performed under sedation or general anaesthesia, chest pain may be absent or not reported. Therefore, routine 12-lead ECGs should be performed after ablation and particular attention applied to detect signs of ischaemia, particularly if multiple or high-energy applications have been delivered at the CS ostium. However, ECG changes and symptoms can occur up to 12 h after ablation.[15] Therefore, an ECG should be performed before discharge and is also indicated if the patient develops chest pain. Repolarization changes (typically T-wave inversion) are frequently observed after catheter ablation of manifest accessory pathways.[16,17] These are attributed to T-wave/cardiac memory and do not correlate with myocardial injury. Therefore, they need to be differentiated from changes driven by ischaemia to avoid unnecessary investigations. Typically, repolarization changes due to cardiac memory will be present as soon as pre-excitation is lost and will not evolve rapidly. However, if due to coronary occlusion, they will evolve over the course of minutes following catheter ablation. Other causes of ST-elevation in right-sided

A



B

Ablation point	Time (s)	Avg Power	Temp (°C)		Impedance (Ω)		Force (g)	
			Max	Avg	Max	Drop	Max	Avg
1	29	29	38	35	141	50	59	17
2	32	29	36	34	119	30	49	15
3	31	29	37	35	121	35	60	15
4	32	29	38	36	121	35	40	12
5	30	29	38	36	123	37	59	26
6	32	29	38	35	115	35	51	13
7	34	29	38	35	109	29	46	13
8	32	29	39	35	118	32	32	8
9	11	28	36	34	108	21	69	7
10	31	29	37	34	109	23	23	5
11	16	33	36	34	126	43	33	10
12	10	37	36	34	120	37	37	10
13	9	37	36	34	119	35	33	10
14	31	39	36	34	118	37	35	9
15	31	39	37	35	140	63	43	15

C

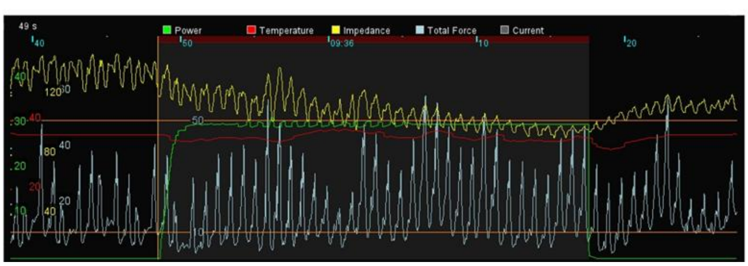


Figure 6 Ablation points and coronary angiography findings for Patient 2. (*A*) Images from the EnSite Precision mapping system indicating the ablation points (round balls) in right and left anterior oblique views, in the left- and right-hand images, respectively. The cluster of ablation points were at the inferior margin of the coronary sinus ostium. (*B*) Ablation parameters for each energy delivery (ablation point). (*C*) Graph showing changes in power, temperature, impedance and contact force during ablation lesion 1. Avg, average; g, grams; s, seconds; W, watts; Ω, ohms.

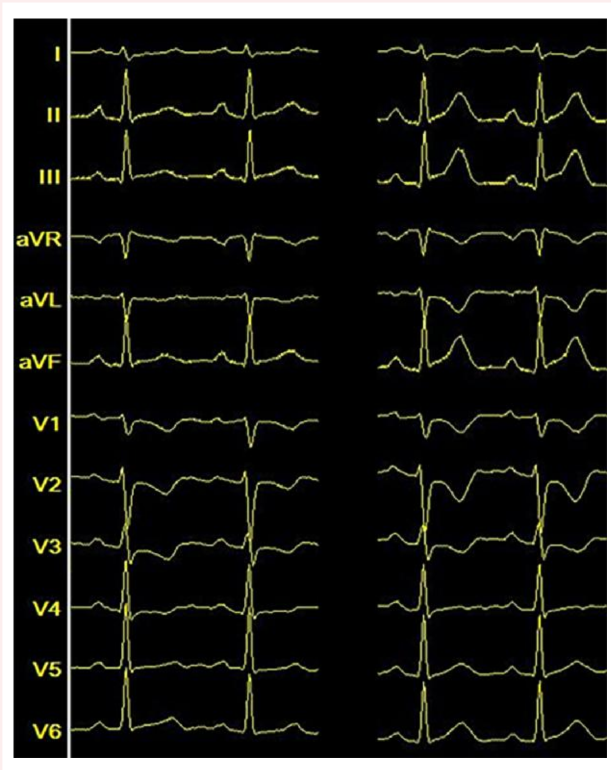


Figure 7 Acute ST-segment changes following ablation (Patient 2). Standard surface 12-lead electrocardiogram signals. Compared with baseline (left-hand panel), new ST-segment elevation was identified after ablation in leads II, III, and aVF and subtle reciprocal depression in leads I and aVL, prompting urgent diagnostic coronary angiography.

procedures include ganglionic plexus stimulation, coronary artery spasm, and air embolism, the latter requiring the presence of a patent foramen ovale.[18]

Catheter ablation is most often performed as an elective procedure, and for SVT, the intended benefits are predominantly to manage symptoms. However, the small risk of coronary artery compromise should be discussed with patients when communicating management options and during the consenting process. Our patients benefited from prompt multi-disciplinary discussions and early coronary catheterization. While good outcomes are reported, this is dependent on early recognition and intervention to avoid lasting myocardial injury, and balloon angioplasty alone has frequently been insufficient to restore blood flow.[15,19,20] In our centre, 2043 cases of RF ablations for SVT were performed over a 5-year period including these two cases, indicating a complication rate of less than 1 in 1000. Our case series may also be relevant to pulsed-field ablation that recently gained regulatory approval for pulmonary vein isolation and left atrial posterior wall ablation. Severe subtotal coronary vasospasm has been reported when applied during cavotricuspid and mitral isthmus ablation, indicating this mode of ablation also affects coronary vasculature integrity when applied in close proximity.[21,22]

Conclusions

In summary, our case series highlights the need to be cautious when ablating near the CS ostium, for regular review of ECGs in the peri- and post-procedural period to identify signs of coronary artery compromise following ablation in this area, and the benefits of a rapid multi-disciplinary approach to manage this. The risk of coronary artery compromise although rare should be communicated to patients undergoing SVT ablation since it can be associated with significant morbidity.

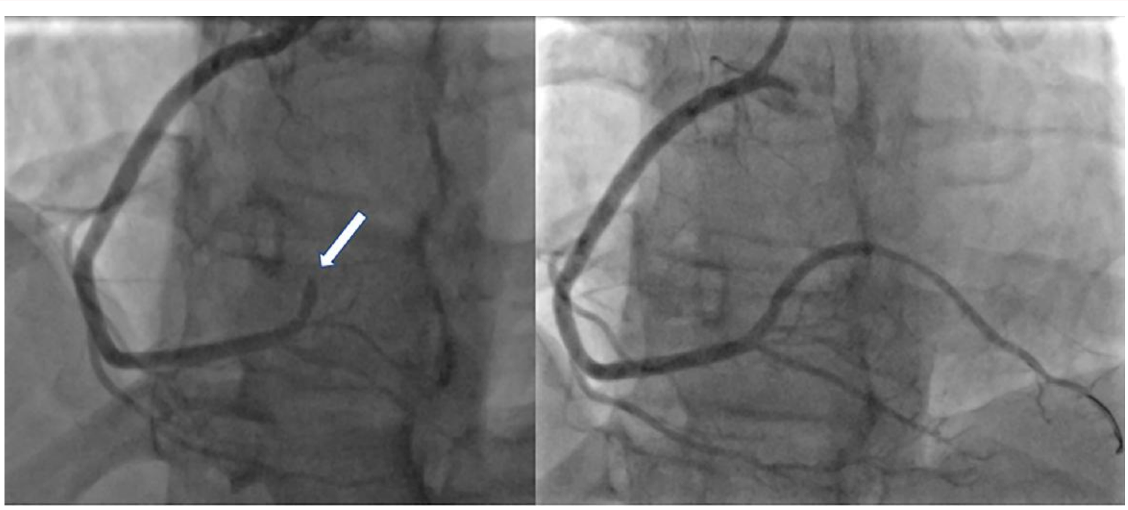


Figure 8 Coronary angiography findings for Patient 2. Coronary angiography identified a total occlusion of the posterior left ventricular branch of the right coronary artery (left image, white arrow). Insertion of a drug-eluting stent restored flow in this vessel with resolution of electrocardiogram changes (right image). See accompanying videos of pre- and post-percutaneous coronary intervention angiography.

Lead author biography

Dr William J. Young graduated from University College London Medical School in 2011 and recently completed his PhD at Queen Mary University of London. He is an Electrophysiology Cardiology Registrar at St Bartholomew's Hospital, London and a NIHR-funded clinical lecturer at Queen Mary University of London.

Supplementary material

Supplementary material is available at *European Heart Journal – Case Reports*.

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Conflict of interest: R.A. is an associated editor for *European Heart Journal: Case Reports*.

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Data availability

The data underlying this manuscript are available in the article and in its online supplementary material.

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