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CASE REPORT
Arrhythmias/electrophysiology

A new method of superior vena cava isolation without phrenic nerve injury by longitudinal ablation parallel to the phrenic nerve: a case report

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Background Superior vena cava (SVC) isolation has improved the outcomes of paroxysmal atrial fibrillation (AF) originating from the SVC. However, right phrenic nerve (PN) injury is a major complication of this procedure. Therefore, in cases where the right atrium (RA)-SVC conduction site is near the PN, tremendous care is required to prevent PN injury.

Case summary Repeated SVC isolation was performed due to the recurrence of SVC-triggered AF. The RA-SVC activation map revealed that the partial conduction block line was detected, and the propagation broke through the gap at the course of the PN site from the RA to the SVC. Since the course of the PN identified at high-output pacing was wide, the SVC was isolated by making longitudinal lines on both sides of the PN in a cranial direction, except for where low-output pacing captured, confirming compound muscle action potential to detect PN injury. Eventually, the SVC was successfully isolated without PN injury, and the sinus rhythm was maintained without antiarrhythmic drugs during a 14-month follow-up period.

Conclusion Superior vena cava isolation was difficult depending on the course of the PN, and some methods to avoid PN injury were reported. However, this method can facilitate safe and effective SVC isolation with the conventional system, including the cases with AF foci located on the course of the PN.

Keywords Atrial fibrillation • Case report • Non-pulmonary vein foci • Phrenic nerve injury • Superior vena cava isolation

Learning points

- Superior vena cava (SVC) isolation improves outcomes in patients with atrial fibrillation. However, right phrenic nerve (PN) injury is one of the major complications of this procedure.
- In case the right atrium-SVC conduction site is near the PN, careful ablation is required to prevent PN injury.
- The course of the PN identified at high- and low-output pacing and the SVC can be isolated by making longitudinal lines on both sides of the PN in a cranial direction, except for where low-output pacing captured, confirming compound muscle action potential.
- This novel approach of SVC isolation may be an effective therapeutic option to prevent PN injury.

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Introduction

Atrial fibrillation (AF) originating from the superior vena cava (SVC) accounts for 37% of the non-pulmonary vein foci (NPVF).[1] Several studies have reported that circumferential SVC isolation has improved outcomes of paroxysmal AF originating from the SVC.[2–4] However, right phrenic nerve (PN) injury is one of the major complications associated with the SVC isolation procedure, with an incidence of up to 5%.[4] A previous study reported that 13% of the SVC isolation procedures could not be performed because of the risk of injury to the PN.[2] The PN passes through the posterolateral aspect of the SVC and the right atrium (RA). Therefore, in cases where the RA-SVC conduction site is near the PN, tremendous care is required to prevent PN injury.

Here, we report a novel method of SVC isolation without PN injury by longitudinal ablation parallel to the PN in a cranial direction in cases where the PN is located on the ablation site.

Timeline

Time	Events
October 2017	Patient developed atrial fibrillation (AF)
February 2018	Patient underwent pulmonary vein (PV) and superior vena cava (SVC) isolation
March 2018	Patient had AF recurrence
September 2018	Patient underwent second session for AF recurrence. SVC re-isolation and cavo-tricuspid isthmus ablation were performed. No PV reconduction was recorded
October 2018	Patient had AF recurrence again with palpitation
February 2019	Patient underwent session for AF recurrence
2020	Patient was followed up, and no arrhythmia was reported

Case presentation

A 65-year-old man complained of palpitation, prompting a visit to our hospital. He had a history of pulmonary vein isolation for paroxysmal AF by hot balloon ablation (SATAKE·HotBalloon Catheter; TORAY, Tokyo, Japan) and underwent additional SVC isolation procedures for AF arising from the SVC. He experienced AF recurrence 7 months after the first procedure and underwent the second procedure. The reconduction between the SVC and the RA along the path of the PN and SVC firing was detected. Point-by-point radio frequency (RF) applications were performed at 15 W/30 s on the PN, and SVC isolation was achieved. However, he had AF recurrence again with palpitation 5 months following the second procedure. In February 2019, he underwent the third procedure for recurrent paroxysmal AF. On admission, the blood pressure was 130/89 mmHg, and the heart rate was 61/min, sinus rhythm.

The SVC-RA map during sinus rhythm using a three-dimensional mapping system (CARTO 3 system version 6; Biosense Webster, Diamond Bar, CA, USA) and a 20-electrode mapping catheter (Pentaray; Biosense Webster) revealed the reconduction between the SVC and the RA (*Figure 1* and *Video 1*). The PN site was identified by pacing at 20 mA/2.0 ms and 5 mA/2.0 ms using the contact force-sensing irrigated ablation catheter (Thermo-Cool Smart touch SF, Biosense Webster). The circumferential conduction block line was detected by the lower threshold function in the CARTO 3 system version 6 (lower threshold at 20%, the total local activation time of 155 ms) except for the course of the PN. Therefore, we attempted SVC isolation by making longitudinal lines on both sides of the course of PN (RF applications; 30 W/30 s). The course of the PN identified at high-output pacing (20 mA/2.0 ms) was wide, so we performed catheter ablation along the path of the PN site except for where low-output pacing (5 mA/2.0 ms) captured (*Figure 1*).

We performed PN pacing at the right subclavian vein and confirmed compound muscle action potential (CMAP) to detect PN injury. Eventually, the SVC was successfully isolated without PN injury by making longitudinal lines on both sides of the PN in a cranial direction (*Figures 1 and 2*). We confirmed the entrance block to the SVC using isoproterenol infusion and the exit block with the SVC pacing and automaticity of the SVC potentials with isoproterenol infusion and adenosine triphosphate (40 mg). Postoperatively, the sinus rhythm was maintained without antiarrhythmic drugs during a 14-month follow-up period.

Discussion

In this case, insufficient low-output ablation to the PN site caused the reconduction of the SVC and subsequent AF recurrence. In this session, the course of the PN was effectively identified by high- and low-output pacing. We adjusted the output to detect precisely the course of the PN. In addition, when catheter ablation was performed near the PN, where high-output pacing captured, we performed CMAP to monitor for the occurrence of PN injury.[5] A previous study reported a method of SVC isolation to avoid PN injury by balloon placement or saline injection by using the epicardial approach to separate the PN and ablation site. Since this method required an epicardial approach, there was an associated risk.[6] Moreover, to avoid PN injury, the ablation line was directed parallel to the PN in a caudal direction. However, this method posed the risk of sinus node injury if the PN extended near to the sinus node and could not be performed in case the PN has continuous proximity from the SVC to the RA.[7] It may be safer to perform ablation towards the end of SVC sleeve than the caudal side because this method does not need to ablate above the course of the PN.

Our case describes a new approach to prevent PN injury by making longitudinal lines on both sides of the PN in a cranial direction. This method could facilitate safe and effective isolation of NPVF in the SVC with the conventional system, including the cases with AF foci located on the course of the PN.

In conclusion, longitudinal linear ablation on both sides of the PN may be a therapeutic option to isolate the SVC and avoid PN injury.

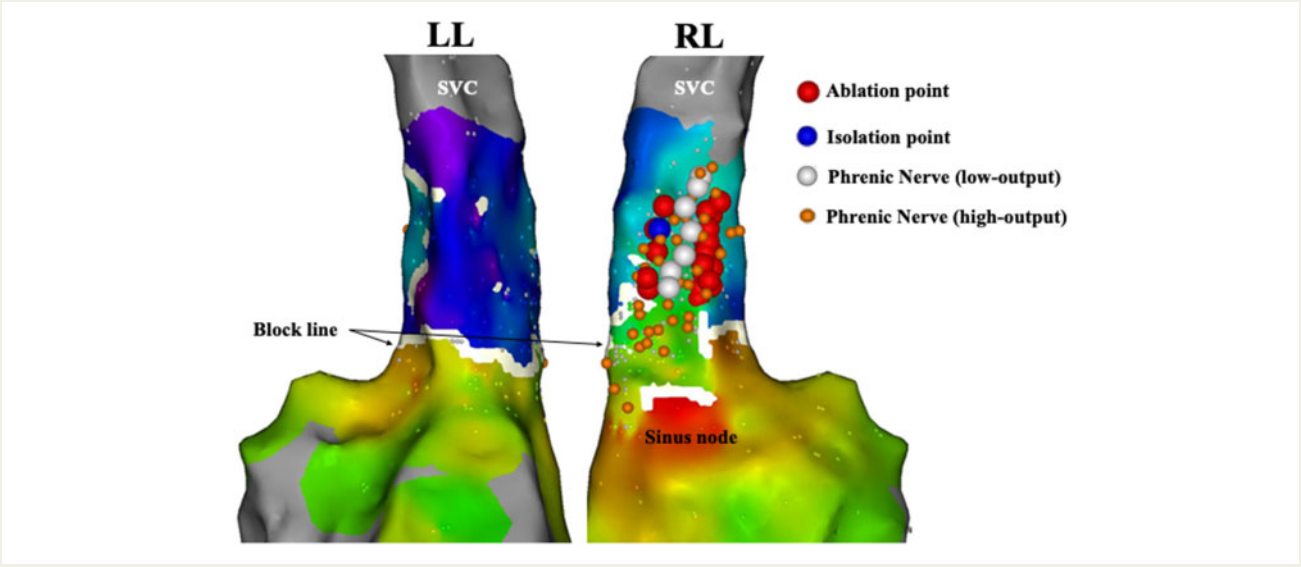


Figure 1 Superior vena cava-right atrium activation map during sinus rhythm shows the reconduction of the superior vena cava. The circumferential conduction block line was detected by a lower threshold function at 20% with a total local activation time of 155 ms (white line). The propagation broke through the gap at the phrenic nerve site from the right atrium to the superior vena cava. The phrenic nerve sites were identified by high- and low-output pacing (white points and orange points). We performed the longitudinal linear ablation from the right atrium to the superior vena cava in a cranial direction (red points). LL, left lateral; RL, right lateral; SVC, superior vena cava.

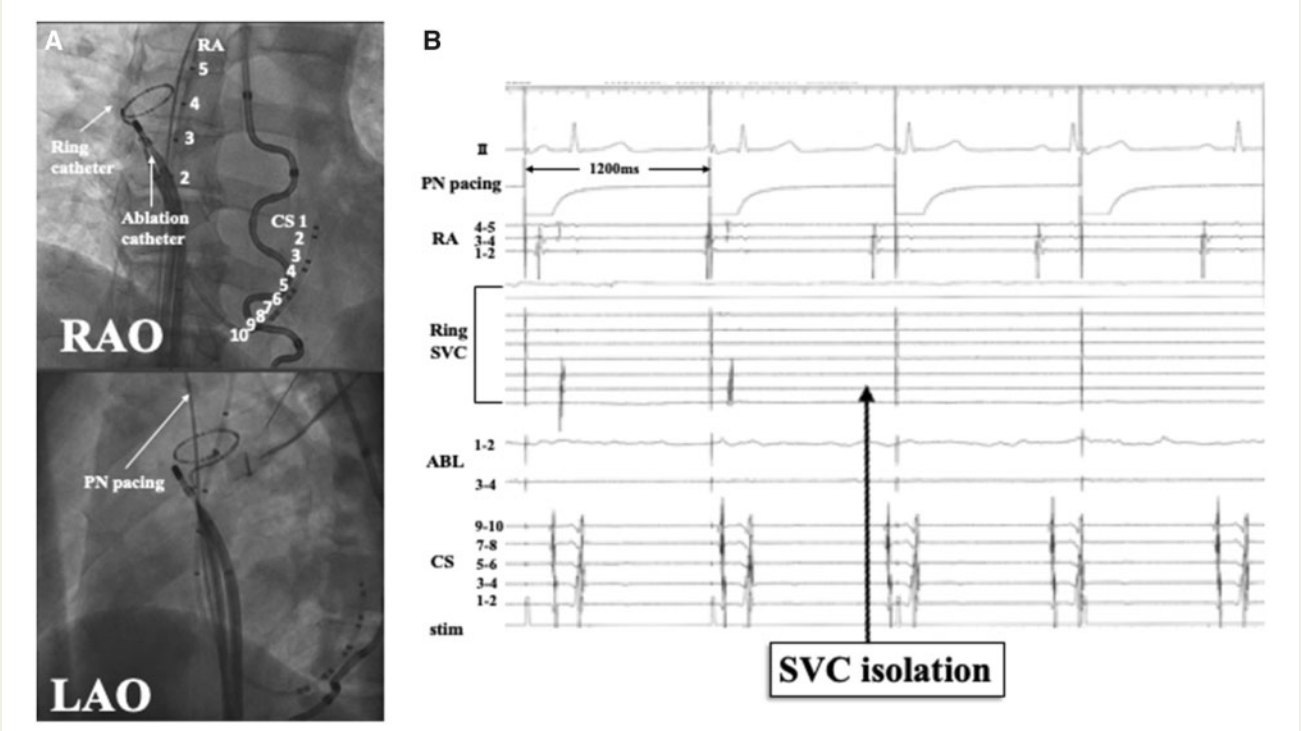
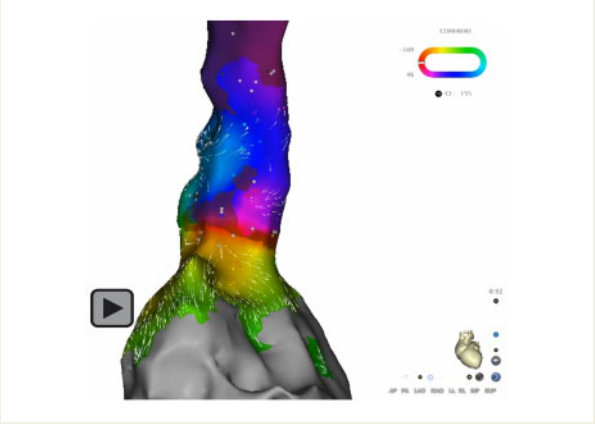
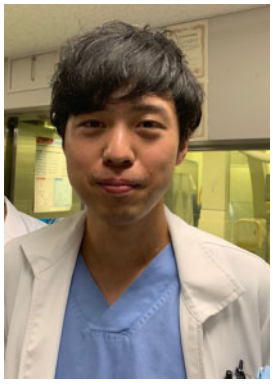


Figure 2 (*A*) The longitudinal linear ablation in a cranial direction was performed with the mapping catheter positioned in the superior vena cava, pacing the phrenic nerve for confirming compound muscle action potential. (*B*) Superior vena cava isolation was performed during the phrenic nerve pacing with 1200 ms interval. The intracardiac electrogram shows superior vena cava isolation from the third beat. ABL, ablation catheter; CS, coronary sinus; LAO, left anterior oblique; PN, phrenic nerve; RA, right atrium; RAO, right anterior oblique; SVC, superior vena cava.



Video 1 The activation map during sinus rhythm shows the reconduction between the superior vena cava and right atrium using Coherent map™ in CARTO 3 system.

Lead author biography



Tomoyuki Arai was born in Tokyo, Japan, in 1989. He received MD degree from Yamagata University School of Medicine, Yamagata, Japan, in 2015 and completed 2 years of Japanese general residency training at National Center for Global Health and Medicine. Since 2017, Dr Arai has been working as an internal medicine resident at Tokyo Metropolitan Hiroo Hospital.

Supplementary material

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

Slide sets: A fully edited slide set detailing this case and suitable for local presentation is available online as Supplementary data.

Consent: The author/s confirm that written consent for submission and publication of this case report including image(s) and associated text has been obtained from the patient in line with COPE guidance.

Conflict of interest: none declared.

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