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CASE REPORT
Arrhythmias/electrophysiology

Absence of shock therapy related to improper sensing of noise on the defibrillation test during subcutaneous implantable cardioverter–defibrillator implantation: a case report

Shota Tamura , Tomotaka Yoshiyama *, Atsushi Doi , and Minoru Yoshiyama

Department of Cardiovascular Medicine, Osaka City University Graduate School of Medicine, 1-4-3 Asahimachi, Abeno-ku, Osaka 545-8585, Japan

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Background Subcutaneous implantable cardioverter–defibrillator (S-ICD) represents an efficient alternative to transvenous ICD in patients who do not require pacing. The intraoperative defibrillation test (DFT) is recommended during S-ICD implantation to confirm appropriate sensing and successful 65-J termination of induced ventricular fibrillation (VF). However, few cases of oversensing of noise inhibiting therapies have been reported.

Case summary We report the case of a 50-year-old man who underwent S-ICD implantation for secondary prevention of sudden cardiac death. Immediately after S-ICD implantation, VF was induced using a 50-Hz burst; however, shock was not delivered owing to sustained noise on the electrogram in the primary vector. Therefore, an external rescue shock was needed at 150 J. We changed the sensing vector from primary to secondary and performed a second DFT. The S-ICD could deliver an appropriate shock and was able to successfully terminate VF without noise markers in the secondary vector. During the second DFT, one back-up pacing was delivered after the shock; the sensing vector then automatically switched from the secondary to the alternate vector. However, noise was observed in the alternate vector despite sinus rhythm restoration.

Discussion The present case demonstrated that noise was recorded in two different vectors during DFT, possibly supporting the hypothesis that the muscle spasm of the diaphragm induced by the 50-Hz burst causes oversensing of noise by the S-ICD.

Keywords Absence of shock therapy • Noise oversensing • Defibrillation test • Subcutaneous implantable cardioverter–defibrillator • Case report

Learning points

- Noise oversensing inhibiting shock therapy should be considered in the defibrillation test (DFT) during subcutaneous implantable cardioverter–defibrillator implantation.
- Muscle spasm of the diaphragm induced by the 50-Hz burst may cause noise oversensing in the DFT.
- The secondary vector, which was further from the diaphragm, may avoid noise oversensing in the DFT.

* Corresponding author. Tel: +81-66645-3801, Fax: +81-66646-6808, Email: tomotaka0324@gmail.com
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Introduction

Subcutaneous implantable cardioverter–defibrillator (S-ICD) is an efficient alternative to transvenous ICD (TV-ICD) in patients not requiring pacing owing to a lower risk of lead-related complications. Subcutaneous implantable cardioverter–defibrillator is suitable for the patients with difficult venous access, or without organic heart disease. A recent meta-analysis reported that S-ICD was similar to TV-ICD in terms of non-lead-related complications, including inappropriate therapy.[1]

The intraoperative defibrillation test (DFT) is recommended during S-ICD implantation to confirm appropriate sensing and successful 65-J termination of induced ventricular fibrillation (VF); however, the value of DFT is questioned in individuals undergoing TV-ICD implantation. Few worrisome cases of noise oversensing during S-ICD implantation inhibiting therapy have been reported.[2] Our case is the first report wherein the noise from two different vectors was measured during DFT.

Timeline

Date	Events
Day 0	The patient was admitted to our hospital because of cardiac arrest caused by ventricular fibrillation (VF), which was successfully terminated via defibrillator shock.
	Transthoracic echocardiography and coronary angiography revealed no abnormalities.
Day 7	Extubation was successfully performed. The patient was diagnosed with idiopathic VF.
Day 25	The patient underwent subcutaneous implantable cardioverter–defibrillator implantation (EMBLEM, Boston Scientific, Marlborough, MA, USA) for secondary prevention of sudden cardiac death.
	During 1st and 2nd defibrillation test, the noise in two different vectors was recorded.
	We determined that the secondary vector without the noise marker is the detection vector.
Day 33	A treadmill exercise test was performed; however, there was no noise on the electrogram in all the vectors.
Day 40	The patient was discharged from the hospital.

Case presentation

A 50-year-old man was admitted to our hospital after resuscitation using an automated external defibrillator following cardiac arrest due to VF. He suddenly collapsed at 11 a.m. while shopping. The emergency medical service team arrived and applied an automated external defibrillator. The documented rhythm was VF that was successfully terminated via a defibrillator shock. There was no family history of syncope or sudden cardiac death. Physical examination on initial presentation revealed normal heart sounds without any murmurs on cardiac auscultation, no rales on respiratory auscultation and no pitting oedema. He was standard height and weight. Thoracic echocardiography indicated good ventricular function without valvular disease. Coronary angiography did not identify any significant stenosis. Based on these results, the patient was diagnosed with idiopathic VF. The patient did not require pacing. Moreover, considering future risk of lead-related complications such as venous obstruction and infection, we believed that S-ICD was more suitable than TV-ICD. A decision was made with him, and S-ICD implantation (EMBLEM, Boston Scientific, Marlborough, MA, USA) was performed for secondary prevention of sudden cardiac death.

The surface electrocardiography screening test for all vectors [primary (proximal electrode ring to can), secondary (distal electrode ring to can), and alternate (distal to proximal electrode)] was positive. Implantation was performed under general anaesthesia using the three-incision technique. The ICD coil was inserted into the standard left parasternal position, and the pulse generator was placed between the anterior surface of the serratus anterior muscle and the posterior surface of the latissimus dorsi muscle by detaching the fibrous tissue in the left mid-axillary line (*Figure 1*). Immediately after S-ICD implantation, there was no sensing failure or noise in any vector. The device automatically selected the primary vector, and one shock zone at 170 b.p.m. and back-up pacing after shock were programmed. After the 2nd DFT, we set the shock zone and conditional zone at 220 and 200 b.p.m., respectively.

To perform DFT, VF was induced using a 50-Hz burst via the programmer. Although VF was induced, shock was not appropriately delivered owing to sustained noise (repeated noise markers) with visualization of fine noise on the electrogram superimposed over the fast ventricular events; therefore, external rescue shock was needed at 150 J, and VF was terminated 32 s after induction. Despite sinus rhythm restoration, noise markers persisted in the primary vector (*Figure 2*). Therefore, we changed the sensing vector from primary to secondary and performed DFT. Subcutaneous implantable cardioverter–defibrillator could deliver an appropriate shock 17 s after induction and successfully terminated VF at 65 J without noise markers in the secondary vector. During the 2nd DFT, back-up pacing was delivered once after the shock; the sensing vector then automatically switched from the secondary to the alternate vector. However, noise markers were found in the alternate vector despite sinus rhythm restoration (*Figure 3*). We changed the vector from alternate to secondary manually and observed that there were no noise markers in the secondary vector. Finally, we deduced that this phenomenon occurred only in specific contexts, such as intraoperative DFT using a 50-Hz burst, and that there were no clinical problems. A treadmill exercise test was performed; however, there was no noise on the electrogram in all the vectors.

Neither appropriate nor inappropriate shocks were delivered during outpatient care after S-ICD implantation.

Discussion

The major findings in the present case are as follows: (i) after VF induction using a 50-Hz burst, shock was not delivered due to

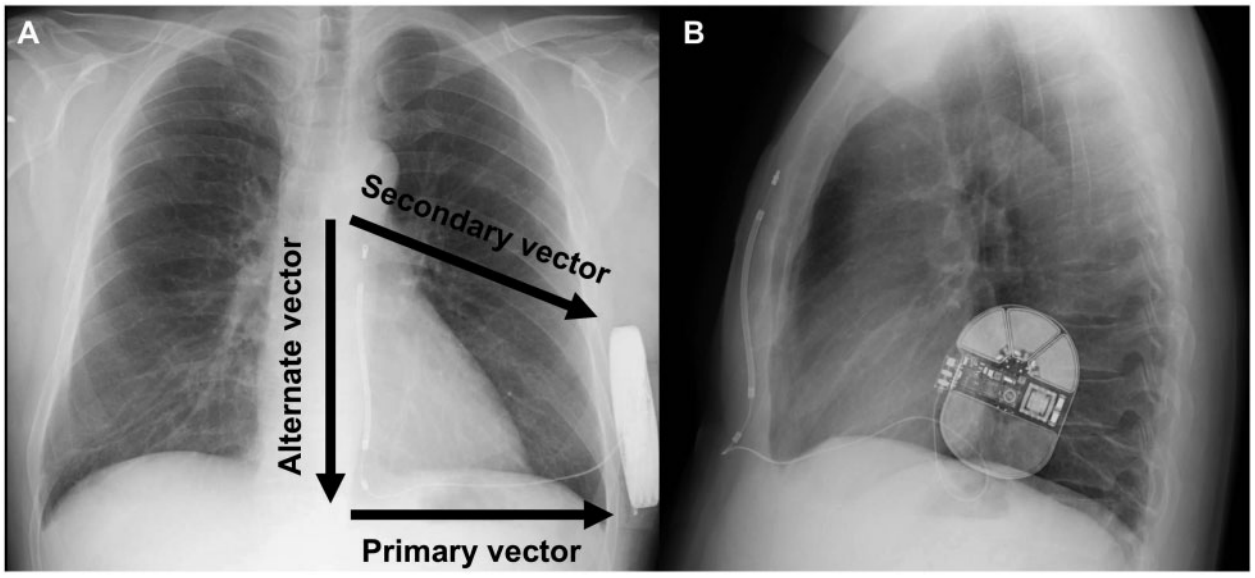

Figure 1 Chest radiography after subcutaneous implantable cardioverter–defibrillator implantation. (*A*) Posterior–anterior chest radiography after subcutaneous implantable cardioverter–defibrillator implantation. The ICD coil was inserted into the standard left parasternal position, and the pulse generator was placed above the serratus anterior muscular fascia and beneath the latissimus dorsi muscle by detaching the fibrous tissue between the muscles in the left mid-axillary line. The figure shows the three bipolar sensing vectors of the subcutaneous implantable cardioverter–defibrillator. The primary vector senses between the proximal lead electrode and the can. The secondary vector senses between the distal lead electrode and the can. The alternate vector senses between the two lead electrodes. (*B*) Lateral chest radiography after subcutaneous implantable cardioverter–defibrillator implantation.

sustained noise in the electrogram in the primary vector proximal to the diaphragm; the noise was still observed in the primary vector after sinus rhythm restoration by an external shock and (ii) the S-ICD could deliver appropriate shock after changing to the secondary vector, although noise was observed in the alternate vector proximal to the diaphragm after sinus rhythm restoration.

Subcutaneous implantable cardioverter–defibrillator is an effective method for preventing sudden cardiac death and is an efficient alternative to TV-ICD in patients not requiring pacing and who are at a risk of device-related complications.[3–5] A recent meta-analysis of case–control studies indicated that S-ICD was similar to TV-ICD in terms of non-lead-related complications, including inappropriate therapy (OR: 0.87; 95% CI: 0.51–1.49), and that the prevalence of inappropriate therapy among S-ICD patients was 8.3%, similar to the result of the EFFORTLESS study.[1,6] However, characteristics of inappropriate therapies were different between S-ICD and TV-ICD. In TV-ICD, inappropriate therapies were mainly driven by aberrant atrial rhythms, whereas in S-ICD, inappropriate shocks were mainly caused by noise or T-wave oversensing.[6]

The SIMPLE study showed no statistically significant difference in the incidence of failure of ventricular arrhythmia termination and death-related arrhythmia between TV-ICD patients with and without DFT [6.5% vs. 5.6%, HR 0.86 (95% CI 0.63–1.17), $P = 0.33$].[7] In the 2015 HRS/EHRA/APHRS/SOLAECE expert consensus statement, DFT was not recommended in TV-ICD patients; however, it was recommended for class I indication in S-ICD patients to confirm appropriate sensing and successful 65-J termination of induced VF.[8] By design, S-ICD has a greater risk of oversensing myopotentials and electromagnetic interference because the sensing electrodes are more distantly spaced and are at greater distances from the ventricular myocardium than TV-ICD. A recent study reported that the absence of therapy or prolonged time to therapy related to noise oversensing during DFT occurred in 6% of S-ICD patients. They suggested that noise oversensing caused by electromagnetic interference was highly unlikely and hypothesized that the 50-Hz burst induced arrhythmia and muscle spasm of the diaphragm and that far-field sensing of the diaphragmatic myopotentials was detected as noise.[2] Previous case report also described that noise caused by involuntary muscle response may inhibit detection of VF during DFT.[9] In our case, shock was not delivered owing to a sustained diagnosis of noise on the electrogram in the primary vector proximal to the diaphragm after a 50-Hz burst, which persisted in the primary vector after sinus rhythm restoration by an external shock. Subcutaneous implantable cardioverter–defibrillator could deliver an appropriate shock after changing to the secondary vector, which was further from the diaphragm, although noise was observed in the alternate vector proximal to the diaphragm after sinus rhythm restoration. These findings suggest that muscle spasm of the diaphragm induced by the 50-Hz burst was the

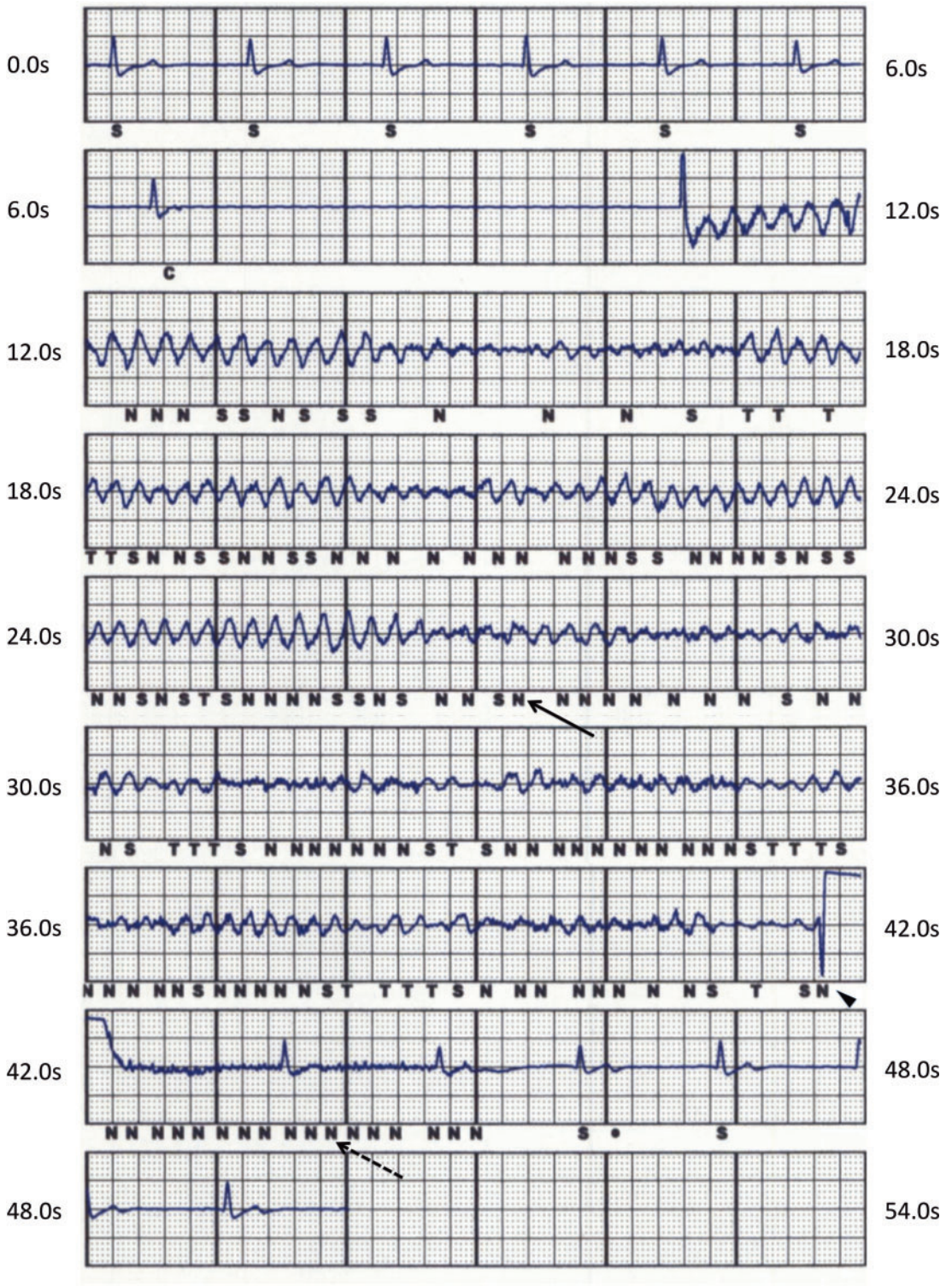

Figure 2 Defibrillation test was performed at the primary vector. Ventricular fibrillation was induced by a 50-Hz burst via the programmer. However, shock was not appropriately delivered owing to sustained noise (repeated noise markers) with visualization of fine noise on the electrogram superimposed over the fast ventricular events (*bold black arrow*); an external rescue shock was needed at 150 J, and ventricular fibrillation was terminated 32 s after induction (*black arrowhead*). Despite the return to sinus rhythm, noise markers persisted in the primary vector (*dashed black arrow*). C, charging; N, noisy beat; S, sensed beat; T, tachy detection.

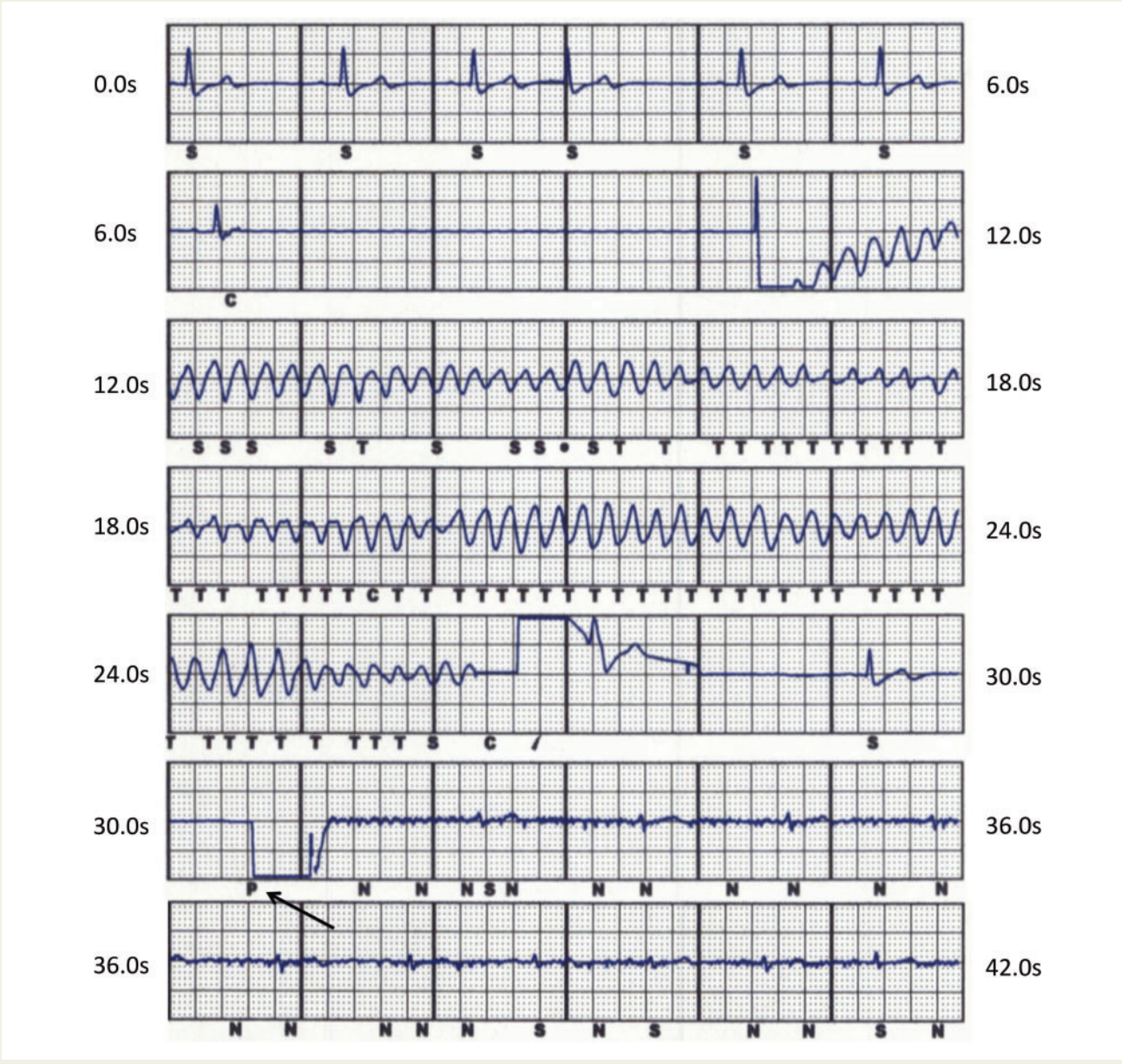

Figure 3 The sensing vector was the secondary vector. Induced ventricular fibrillation was successfully terminated without a noise marker in the secondary vector. Back-up pacing was delivered once after the shock (*bold black arrow*); the sensing vector then automatically switched from the secondary to the alternate vector. However, noise markers were found in the alternate vector despite sinus rhythm restoration. C, charging; N, noisy beat; S, sensed beat; T, tachy detection.

cause of noise oversensing in the DFT. However, we did not use a muscle relaxant during anaesthesia and thus could not prove this hypothesis.

Conclusions

We reported a case with absence of shock therapy owing to improper sensing of noise on DFT during S-ICD implantation. Our case is the first report that recorded the noise in two different vectors after VF induction by a 50-Hz burst during DFT. This finding might support the hypothesis that muscle spasm of the diaphragm induced by the 50-Hz burst causes noise oversensing by S-ICD.

Lead author biography

Shota Tamura, MD, belongs to the Department of Internal Medicine and Cardiology in Osaka City University Graduate School of Medicine. He majors in arrhythmia and his research focuses on catheter ablation for atrial fibrillation.

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 authors 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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