A CASE FOR EDUCATION

Sequential approach for the prevention of phrenic nerve injuries during epicardial radiofrequency ablation of ventricular tachycardia

Kenichi Tani, MD,* Mitsuru Takami, MD, PhD,*† Hiroyuki Kawamori, MD, PhD,* Takayoshi Toba, MD, PhD,* Shunsuke Kakizaki, MD, PhD,* Koji Fukuzawa, MD, PhD*†

*From the *Division of Cardiovascular Medicine, Department of Internal Medicine, Kobe University Graduate School of Medicine, Kobe, Japan, and †Section of Arrhythmia, Division of Cardiovascular Medicine, Department of Internal Medicine, Kobe University Graduate School of Medicine, Kobe, Japan.*

Introduction

Catheter ablation of ventricular tachycardia (VT) associated with structural heart disease is still challenging. An epicardial approach is often needed for patients with epicardial or subepicardial arrhythmogenic origins of ventricles. However, even after a successful approach in the epicardial space, limited or no radiofrequency (RF) catheter ablation can be performed owing to the proximity to the phrenic nerve (PN) or a coronary artery.[1] Several techniques for reducing the risk of PN injury have been proposed during epicardial RF catheter ablation: air/saline injections into the epicardial space and balloon inflations in the epicardial space.[2,3] However, the effect of each technique on preventing PN injury during catheter ablation procedures is not known. Here, we performed those techniques sequentially during epicardial catheter ablation of VT, and then the efficacy of each technique for reducing the PN capture area could be assessed.

Case report

A 59-year-old man was transferred to our hospital with palpitations and implantable cardioverter-defibrillator shocks. An electrocardiogram revealed an incessant VT (Figure 1A). The patient's blood pressure was 138/87 mm Hg, while pulse rate was 80 pulsations per minute. The oxygen saturation was 99% (room air). Echocardiography showed that the left ventricle (LV) wall motion exhibited diffuse severe hypokinesis (LV ejection fraction: 32%). The VT recurred easily; therefore, the patient was sedated and intubated and then admitted to an intensive care unit.

Past history

The patient had diastolic phase hypertrophic cardiomyopathy and a history of 3 catheter ablation procedures for multiple VTs. The first and second catheter ablation sessions for VT were performed through an endocardial approach when the patient was aged 55 and 57. No low voltage/scar or abnormal electrical potentials were observed in the LV endocardium. Long-duration endocardial RF applications were able to suppress some of the VTs, but the effect was limited for other VTs. As a recurrent VT storm was observed just after the second catheter ablation, we performed catheter ablation with an epicardial approach. One of the clinical VTs could be eliminated by RF applications on the LV anterior epicardium. Another VT was induced by burst pacing, and a good pace map was obtained in the basal-lateral area of the LV epicardium. However, in this area, pacing from the ablation catheter captured the left PN. Therefore, only a limited RF application could be delivered.

Ablation procedure

The morphology of the clinical VT (Figure 1A) was similar to that of the VT, which could not be ablated owing to the proximity of the left PN during the last epicardial ablation. We decided to perform the epicardial approach again, and we successfully performed an epicardial puncture and inserted a steerable sheath (Agilis; Abbott, Abbott Park, IL) into the epicardial space. Clinical VT incessantly occurred. An activation map that used a decapolar mapping catheter (DecaNav; Biosense Webster, Irvine, CA) during VT showed that the activation wavefront propagated from the basal-lateral area to the anterior and apex of the LV epicardium

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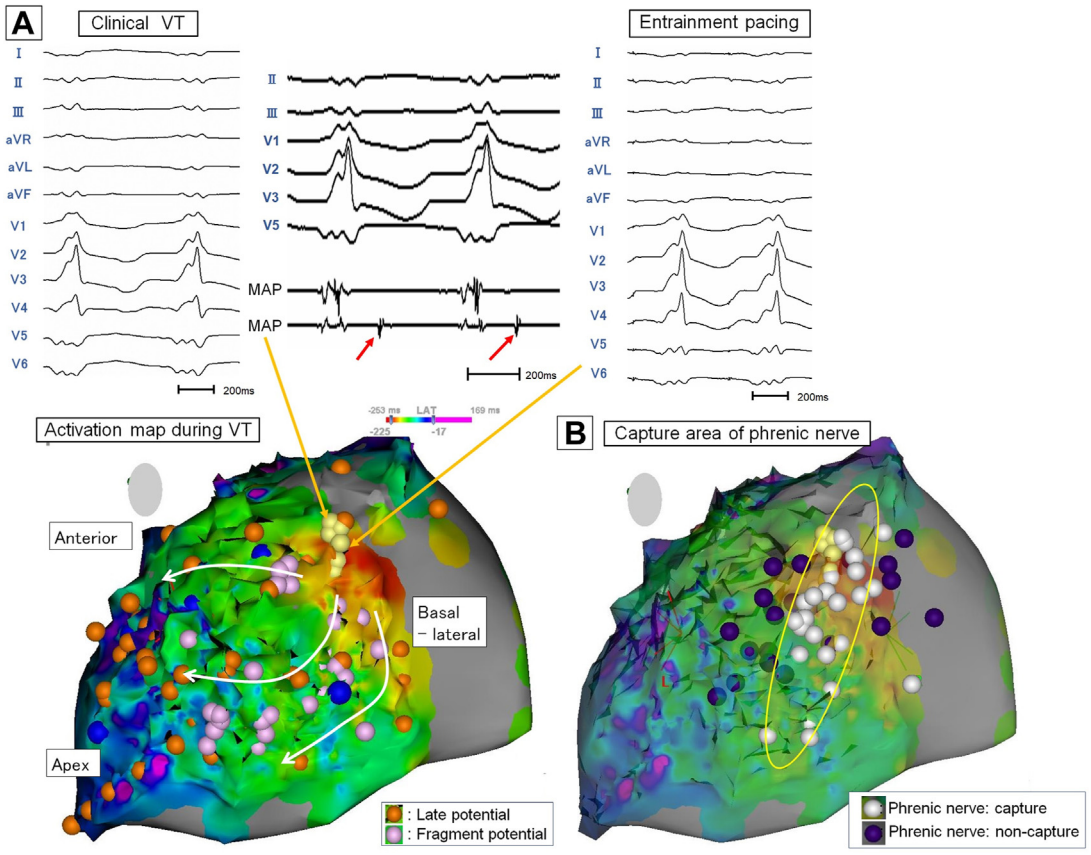

Figure 1 Electroanatomical map of the left ventricle (LV) epicardium. **A:** Clinical ventricular tachycardia (VT) (left upper panel) incessantly occurred during the procedure. The activation map shows that the activation wavefront of the VT propagated from the high basal-lateral to the anterior and lateral LV. A decapolar mapping catheter recorded a diastolic potential (red arrow in the middle upper panel) during the VT in the high basal-lateral LV. Entrainment pacing from this area revealed the concealed entrainment of the VT (right upper panel). **B:** The white dot shows the area where the left phrenic nerve was captured at an output of 5 V. MAP = mapping catheter.

(Figure 1A). Diastolic potentials during VT were observed at a high basal-lateral site, and entrainment pacing at that site exhibited concealed entrainment (Figure 1A). These findings suggest that the area was part of the central isthmus of the VT circuit (yellow tags in Figure 1A). However, pacing from the ablation catheter (Thermocool STSF; Biosense Webster) at a 5 V output in the central isthmus widely captured the left PN (Figure 1B). Therefore, we performed several techniques sequentially to avoid PN injury and started with a less invasive technique.

Continuous PN capture during RF application

First, a 6F electrode catheter (EP star; Japan Lifeline, Tokyo, Japan) was inserted into the left subclavian vein to capture the left PN (Figure 2). Just before each RF application on the LV epicardium, pacing was performed from the ablation catheter to confirm the noncapture of the PN. During RF application, continuous left PN capture at 50 pulsations per minute was monitored by pacing from an electrode catheter in the left subclavian vein. If a loss of pacing capture or weakening of PN capture was observed, the RF application was immediately stopped. By using this method, RF applications could be delivered on the lateral LV epicardium (Figure 2A–2C). The monitoring of continuous pacing capture of the PN is usually performed during pulmonary vein isolation with a cryoballoon. This technique is applicable for epicardial VT ablation. However, in the present case, there was still a large area that captured the left PN from the ablation catheter, which prevented the delivery of RF applications at the critical isthmus of the VT circuit.

Saline injection into the pericardial space

Second, we injected a saline solution into the pericardial space to provide a distance between the ablation catheter and the left PN (Figure 2D). We carefully injected 10 mL of saline at a time every 20–30 seconds while monitoring the blood pressure. After a total of 150 mL of saline was injected, pacing from the ablation catheter showed that the left PN capture area had dramatically decreased (Figure 2E). Also, saline injection significantly improved the manipulation of the ablation catheter in the epicardial space. We could then deliver RF applications in that area (Figure 2F). The frequency of VT gradually decreased. However, the critical isthmus on the high basal-lateral LV epicardium was not completely ablated because the PN was still captured in the area after the saline injection. Also, it was difficult to inject any further saline owing to a low systolic blood pressure

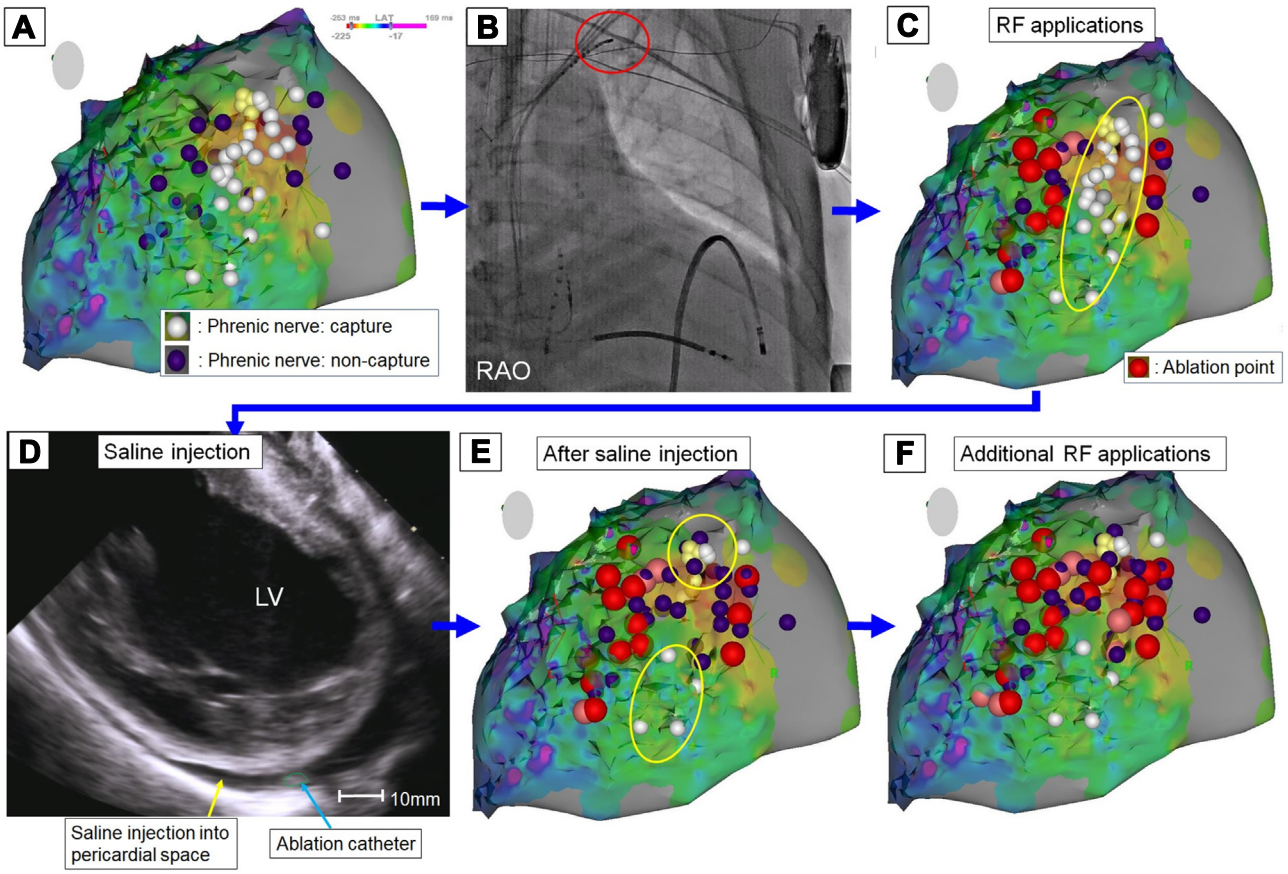

Figure 2 Pacing from the subclavian vein and saline injection. **A:** The capture area of the phrenic nerve (PN) (*white dots*). **B:** A 6F electrode catheter was inserted into the left subclavian vein to capture left PN (*red circle*). During radiofrequency (RF) application, the continuous left PN capture from the electrode catheter was monitored. **C:** RF applications could be delivered in the lateral left ventricle (LV) at areas other than where the direct capture of the PN was observed (*yellow circle*). **D:** Saline was injected into the epicardial space to maintain a distance between the ablation catheter and left PN. The yellow arrow indicates the saline content in the epicardial space. The light blue arrow indicates the tip of the ablation catheter. **E:** After the saline injection, the area of PN capture was significantly decreased (*yellow circle*). **F:** Additional RF applications could be performed. RAO = right anterior oblique.

below 70 mm Hg. We halted the injection and aspirated the injected saline from the epicardial space.

The saline injection method was easy to perform and worked well to perform additional RF applications in the present case. Among the shortcomings of this method were a drop in blood pressure owing to the saline injected into the epicardial space. In addition, it was difficult to target the pooling of saline in specific areas close to the PN.

Balloon inflation in the epicardial space

Third, we performed a balloon inflation method in the epicardial space to displace the PN. Two wires were inserted into the epicardial space through the Agilis steerable sheath (Figure 3A). The Agilis sheath was temporarily withdrawn, then a 6F long guiding sheath (Destination®; Terumo, Tokyo, Japan) and Agilis sheath were inserted into the epicardial space over each wire (Figure 3B). An ablation catheter was inserted via the Agilis sheath and placed in the target area. A balloon catheter (Advance® 35LP 6 × 20 mm; Cook Medical Japan, Tokyo, Japan) was inserted via the 6F sheath into the epicardial space over the wire. The balloon catheter delivery and balloon inflation at the target area were conducted by 2 cardiac interventionalists (Figure 3C). After balloon inflation, pacing from the ablation catheter revealed no capture of the PN in the target area. Using this method, we successfully delivered additional RF applications in the central isthmus of the VT circuit (Figure 3D). The advantage of this technique is that PN displacement can be performed in the target area by delivering and inflating the balloon. At first, an electrophysiological physician delivered the ablation catheter to the target area, and then 2 cardiac interventionalists delivered the balloon catheter as a guide for the ablation catheter position. Owing to their collaboration, there was no difficulty in delivering and inflating the balloon catheter in the present case.

The clinical VT was eliminated, and no other VTs were induced after the RF applications.

After the catheter ablation, a chest radiograph showed no signs of PN injury. The patient was discharged after 12 days, and a regular device check at the outpatient clinic showed that the patient had no VT recurrences and that he had been free from any events during a 10-month follow-up period.

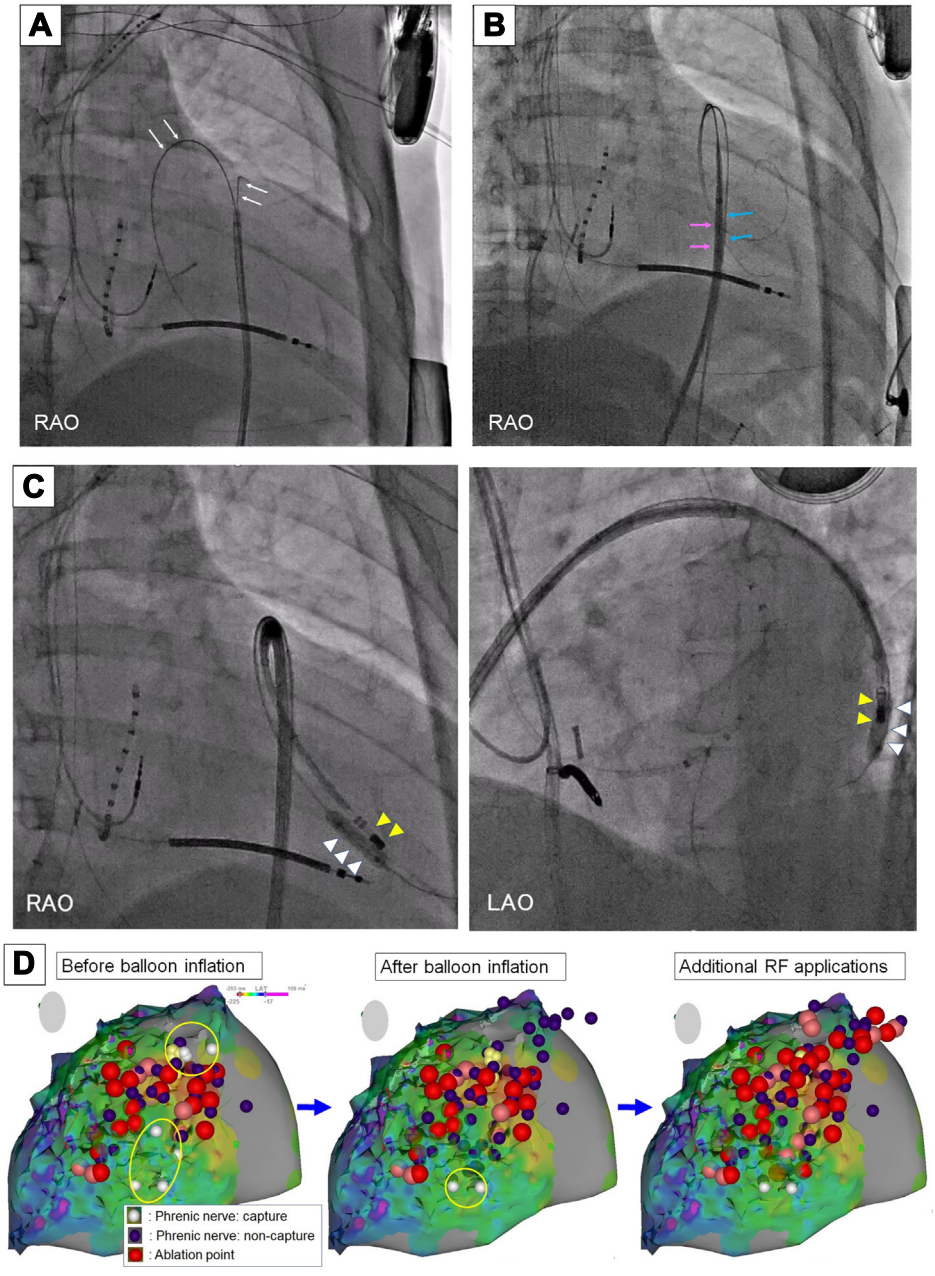

Figure 3 Balloon inflation in the epicardial space. **A:** Two wires (*white arrows*) were inserted from the Agilis sheath (Abbott). Then, the Agilis sheath was temporally extracted. **B:** A 6F long guiding sheath (*blue arrows*) and Agilis sheath (*pink arrows*) were inserted into the epicardial space over each wire. **C:** The balloon catheter was delivered as a guide for the ablation catheter position (*yellow triangles*), and the balloon was inflated at the target area (*white triangles*). **D:** An area of direct phrenic nerve capture still existed before balloon inflation (*yellow circle* in left panel). After balloon inflation, the phrenic nerve capture area decreased (*yellow circle* in middle panel). Additional radiofrequency applications could be delivered (right panel). LAO = left anterior oblique; RAO = right anterior oblique, RF = radiofrequency.

Discussion

Phrenic nerve and epicardial ablation failure

Catheter ablation of VT with an epicardial approach is often needed in patients with nonischemic cardiomyopathy. Examination of the gross dissection of the PNs in 19 cadavers showed that the left PN descends on the posterolateral wall of the LV in 79% of cases, and descends on the anterolateral wall in about 21%.[4] Baldinger and colleagues[1] reported the reasons for epicardial ablation failure and the effect on outcomes in 277 patients. The failure to identify an epicardial target for ablation and close proximity to a coronary artery and PN were the major reasons for epicardial ablation failure. In particular, in the LV basal-lateral and LV mid-lateral target areas, limited or no epicardial RF applications were delivered in 10% and 26% of patients, respectively, because of the close proximity of the left PN.

Preventive strategies of phrenic nerve injury

Di Biase and colleagues[2] compared the methods for separating the PN from the epicardial surface to prevent PN injury during catheter ablation in 8 cases. First, they inflated a large balloon in the pericardial space. Next, they introduced saline, which was followed by the introduction of air in the pericardial space. They injected a combination of saline and air in the final step. As opposed to this sequence, we followed a different order in the present case: (1) continuous PN capture during RF application, (2) saline injection, and (3) balloon inflation. This sequence was followed because we thought that saline injection was a less invasive approach than balloon inflation technique. Moreover, it was an easy process to inject saline into the pericardial space from the ablation catheter sheath. When it was observed that the blood pressure drop was significant, we could promptly aspirate the saline. In contrast, the balloon inflation technique needs additional sheath insertion into the pericardial space. Also, the delivery and manipulation of the balloon catheter to the target area requires some interventionist skills. Okubo and colleagues[3] reported that the displacement of the PN with a balloon could be a safe solution, leading to complete epicardial VT ablation. Two types of balloons are available, namely valvuloplasty balloons and endovascular therapy (EVT) balloons. Valvuloplasty balloons have been reported to be more effective than EVT balloons in reducing the area of capturing the PN because of the larger balloon size. However, valvuloplasty balloons require a relatively large guiding sheath; therefore, we opted for EVT balloons. In the present case, we did not inject air into the pericardial space because it carries the risk of increasing the defibrillation threshold.[5]

Di Biase and colleagues[2] reported that the success rate in the prevention of PN capture was 3 of 8 (37%) patients by balloon inflation, 0 of 8 (0%) by only saline injection, 2 of 8 (26%) by only air injection, and 7 of 8 (88%) by a combination of saline and air. In the present case, complete elimination of PN capture area was not achieved by only saline injection; however, the PN capture area was significantly reduced after saline injection. We then targeted the remaining PN capture area using the balloon inflation technique. Finally, we successfully performed RF applications in a wide area close to the PN by a combination of these techniques. A complete elimination of PN capture area by a single technique would be ideal, but the cardiac size, the volume of the pericardial space, and the distance from the epicardium to the PN are all different in each individual. Therefore, following a sequential approach using less invasive techniques is one of the strategies to prevent PN injury during epicardial catheter ablations.

Conclusion

PN injury is one of the problems encountered in the epicardial catheter ablation of VT. A preventive strategy for PN injury starting with less invasive techniques could be useful for epicardial VT ablation.

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