A Steam Pop Detected by Intracardiac Echocardiography During Catheter Ablation of the Left Ventricular Papillary Muscle

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Summary

A 60-year-old female with premature ventricular contractions (PVCs) originating from the bottom of the posteromedial papillary muscle of the left ventricle underwent radiofrequency catheter ablation (RFCA) using an irrigated-tip catheter. During ablation of the PVCs, a loud steam pop was observed. Intracardiac echocardiography (ICE) revealed a growing, hyperechogenic intramyocardial microbubble formation around the catheter tip. The formation disappeared slowly and completely, leaving an endocardial laceration without pericardial effusion. ICE imaging is valuable during a difficult RFCA procedure, because ICE reveals the exact anatomical position of the catheter and thus allows rapid evaluation of the occurrence of steam popping and any possible subsequent complication.

Key words: Premature ventricular contraction, Irrigated catheter

Radiofrequency catheter ablation (RFCA) is useful for treating cardiac arrhythmias. The use of a conventional ablation catheter with a nonirrigated electrode is associated with the risk of thrombus formation at the catheter tip during high-power RF delivery. In regions where the blood flow is not enough for cooling of the catheter, the temperature of the catheter electrode may increase and reach the level prohibiting delivery of more RF energy. As a result, effective RF energy is not provided. Recently, irrigated catheters have been used to minimize the risk of thrombus formation and to improve the safety of high-power RFCA. However, irrigated catheters are associated with the steam popping phenomenon; excessive ablation may trigger uncontrolled overheating of myocardial tissue. More recently, intracardiac echocardiography (ICE) has gained recognition as a very helpful technique in evaluation of cardiac anatomical structure during RFCA procedures, facilitating three-dimensional (3D) electroanatomic mapping. We report a case with steam popping and subsequent myocardial destruction detected by ICE during RFCA of the left ventricular papillary muscle (LVPM).

Case Report

A 60-year-old female was referred to our hospital for the treatment of symptomatic premature ventricular contractions (PVCs) exhibiting a right bundle branch block/ left axis morphology and a wide QRS pattern (145 ms) (Figure 1A). The patient complained of chest discomfort and felt that her heartbeats were skipping. According to a 24-hour Holter electrocardiogram, the total number of PVCs was 17,200 beats/day (14% of the total), including 111 episodes of ventricular couplets. However, nonsustained ventricular tachycardia was not recorded. The PVCs were more frequent during the day than at night. During the recording of the Holter electrocardiogram, these symptoms were associated with the frequent PVCs. In addition, mild edema of the bilateral lower extremities was seen, and the plasma brain natriuretic peptide level was slightly high (48 pg/mL). The patient’s transthoracic echocardiography was normal. Although the association between the edema and the frequent PVCs was unclear, the diuretic drug azosemide (30 mg/day p.o.) was administered. Aprindine hydrochloride (40 mg/day) and metoprolol (5 mg/day) were administered but could not suppress the PVCs. Therefore, the treatment of catheter ablation was chosen after obtaining informed consent from the patient and her family. In the electrophysiologic study, mapping of left ventricular (LV) endocardial activation was performed using a catheter with a 3.5-mm tip electrode featuring six small irrigation holes (Navistar® ThermoCool® C-curve catheter; Biosense Webster Inc., Diamond Bar, CA, USA) via a retrograde aortic approach employing a 3D electroanatomical mapping system (Carto® 3; Biosense Webster, Inc.). The PVCs were found to originate in the LV inferoseptal region (Figure 2). ICE (SoundStar® Catheter; Biosense Webster, Inc.) showed that the catheter tip was located at the bottom of the posteromedial papillary muscle (PM). Twenty RFCAs were...
delivered at 35-40 W with appropriate initial impedances (range: 90-119 ohms), each for 90 seconds, on the lateral and septal sides of the bottom of the posteromedial PM with a saline irrigation flow rate of 30 mL/minute (Figure 2); however, the PVCs were not affected. Then the catheter was placed in a deeper position (between the bottom of the posteromedial PM and the inferior septal wall of LV; Figure 3A); the catheter tip was thus located at the earliest PVC activation site (Figure 4), and optimal pace mapping was obtained within one minute after RFCA was started. No change in either catheter temperature (range: 34-39°C; median, 37°C) or impedance (range: 85-99 ohms; median, 88 ohms) was apparent during ablation. However, RFCA was immediately terminated at 87 seconds because of a loud popping sound. ICE revealed a suddenly growing, hyperechogenic, intramyocardial micro-bubble formation (11 mm in diameter) around the catheter tip (Figure 3B and C), the volume of which then decreased slowly. The formation disappeared completely after approximately 30 seconds, leaving a small endocardial laceration (Figure 3D). Continuous ICE revealed no peri-cardial effusion or mitral regurgitation. Fortunately, the mildly sedated patient was asymptomatic; no recurrence of the PVC was noted after the last application. A Holter electrocardiogram two months after RFCA showed a significant decrease in the number of PVCs (1,504 beats/day). The target PVC disappeared, but other PVCs exhibiting a right bundle branch block/right axis morphology remained. As a result, the patient’s symptoms have subsided.

**Discussion**

Catheter ablation of various PVCs is an effective treatment option because of advancements in catheter appliances and imaging instruments. Our patient was troubled with daily symptoms due to advancements in catheter appliances and imaging instruments. Our patient was troubled with daily symptoms due to frequent PVCs originating from the LVPM and required a diuretic for edema. Catheter ablation was chosen after the failure of pharmacotherapy. In the Japanese guidelines for nonpharmacotherapy of cardiac arrhythmias,7) the indication of the catheter ablation for patients with frequent PVCs, who have deterioration of quality of life or heart failure, and for whom pharmacotherapy is ineffective is acceptable as Class I. However, the catheter stability is difficult to obtain during mapping and ablation of the LVPM because of the anatomical complexity. Therefore, catheter ablation of the LVPM is challenging.

Irrigated catheters were developed to minimize the risk of thrombus formation at the catheter electrode during RF delivery at high-power and to perform effective RFCA of deep, large lesions.1) However, cooling produced by irrigation of a catheter electrode increases the disparity between myocardial tissue and catheter electrode temperatures during RFCA, resulting in an occurrence of “steam pop.”1,2) During RFCA, steam popping reflects boiling of water content in the myocardium because of overheating. If we could predict steam pops, we would be able to terminate the RFCA application and avoid complications associated with them. Seiler, et al. reported that a decrease in impedance of at least 18 ohms during RFCA using an
Figure 3. Images of intracardiac echocardiography (ICE) inserted in the right ventricle (RV). The positions of the ablation catheter tip (green semi-ellipse with green arrow) and its shaft (white arrow) at the start of ablation are depicted between the bottom of the posteromedial PM (white arrowhead) and the inferoseptal LV wall on the ICE image (A). ICE imaging showed a hyperechogenic intramycocardial formation (yellow arrowheads) around the catheter tip at the moment of occurrence of the steam pop (B). ICE imaging showed that the formation suddenly expanded to a sphere over the course of several seconds (C). ICE image showed an endocardial laceration (yellow arrows), which remained in the location where the round formation disappeared 30 seconds after the end of ablation (D).

irrigated catheter was associated with the occurrence of steam pop. However, in a recent prospective observational study using the same irrigated catheter that we used, only 20% of RF applications with steam pops were associated with a preceding impedance change, and steam pops could not be predicted from catheter impedance measurements. ICE is a very informative tool when evaluating cardiac anatomical structures (e.g., PM) and catheter position during RFCA procedures, facilitating 3D electroanatomic mapping. Takagi, et al. described a real-time visualization of steam pops on ICE imaging in a canine model for the first time. Kondo, et al. reported that the focal microbubbles formation was observed with ICE just before steam pop initiation during RFCA in a piglet. In an open-chest ovine model, Wright, et al. discovered that hyperechogenic gas formations appeared 3.0 ± 1.1 seconds (2.3-4.7 seconds) prior to an audible pop during RFCA of the cardiac endocardium. When the delivery of RF energy had been stopped just after the appearance of these formations on the ICE image, the formations disappeared and did not lead to a steam pop. However, there are few reports of steam popping detected by ICE in a human heart. Tokuda, et al. detected a silent steam pop by ICE image during RFCA at a human LV inferior wall. Before the steam pop, there was no change in the catheter impedance or ICE image. Therefore, it is difficult to predict an unexpected steam pop by ICE imaging during a clinical RFCA procedure.

In our case, even a substantial number of RFCAs around the PM did not result in success, but high-energy
RFCA (40 W) at the deep position between the PM and LV septal wall was able to abolish the patient’s PVCs for the first time. Therefore, the PVCs were thought to originate in the deep layer of the myocardial wall. In addition, the irrigated catheter that we used was not equipped with a sensor measuring the contact force. Thus, objective levels of the contact force during the ablation were not clear. However, when the catheter tip was wedged in the small gap between the PM and the LV septal wall (as shown by ICE imaging), the catheter may have had a high contact force. Ikeda, et al noted that the incidence of a steam pop increased with both increasing RF power and contact force. Therefore, in our case, excessive RFCA energy with a high contact force was delivered to the local deep myocardium, which may have caused an audible steam pop. To the best of our knowledge, this is the first report to include ICE images showing a steam pop during RFCA of LVPM. Since there was neither a change in the catheter measurements (temperature and/or impedance) nor a change in the ICE image before the steam pop, it was difficult to terminate RFCA to prevent a steam pop when the catheter tip is in a deep position and, moreover, we can detect the early development of steam pops and subsequent complications.

**Conclusion**

We describe a case involving a steam pop and subsequent myocardial destruction detected using ICE during RFCA of the PVC originating from LVPM. RFCA with an irrigated ablation catheter is useful for the treatment of arrhythmia but is not completely safe; thus, ICE monitoring is important to quickly detect the position of the ablation catheter and the occurrence of a steam pop and complications.

**Disclosures**

**Conflicts of interest:** The authors have no conflict of interest to disclose.

**References**

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