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RHYTHM DISORDERS AND ELECTROPHYSIOLOGY

CASE REPORT: CLINICAL CASE

Cryoballoon Breach in Atrial Fibrillation Ablation Resulting in Massive Gas Emboli and Hemodynamic Compromise

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ABSTRACT

Cryoballoon ablations have an excellent safety profile. We present a case of a 58-year-old woman who experienced an unlikely complication of a cryoballoon breach resulting in massive gas emboli and transient hemodynamic compromise. Gas emboli are associated with high morbidity and mortality, and early recognition is essential to successful recovery. (JACC Case Rep. 2024;29:102765) Crown Copyright © 2024 Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

HISTORY OF PRESENTATION

A 58-year-old woman with a history of symptomatic paroxysmal atrial fibrillation (AF) with fast ventricular response who was unresponsive to medical therapy underwent cryoballoon pulmonary vein isolation (PVI). On the day of the procedure, she was in sinus rhythm, with premature atrial contractions between 60 and 70 beats/min (**Figure 1A**). She was intubated while under general anesthesia in the electrophysiology laboratory. Right femoral venous access was gained, and access to the left atrium was achieved through a transseptal puncture in the usual fashion. The patient was heparinized to achieve a target activated clotting time of 350 to 500 seconds. Pulmonary vein (PV) angiography was undertaken and demonstrated standard anatomy. A 28-mm cryoballoon (Arctic Front Advance, Medtronic) housed within a dedicated delivery sheath (FlexCath Advance, Medtronic) was used to carry out cryoablation to the left PVs without complications. Attention then turned to the right-sided PVs; a good seal was achieved at the right superior PV, with PVI occurring at 25 seconds. Shortly afterward, the patient's blood pressure began dropping to the 50s mm Hg systolic. At that time, the CryoConsole (Medtronic) alarmed with error code "50005," stating "The safety system has detected fluid in the catheter and stopped the injection."

TAKE-HOME MESSAGES

- Gas embolism is a rare yet serious complication of cryoablation procedures.
- Recognition of gas embolisms is crucial for acute and potentially lifesaving management when faced with this rare complication.

PAST MEDICAL HISTORY

The patient's relevant cardiac history included paroxysmal AF with a $CHADS_2$ of 0, and she was

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ABBREVIATIONS AND ACRONYMS

AF = atrial fibrillation

CICU = cardiac intensive care unit

LV = left ventricle

N_2O = nitrous oxide

PV = pulmonary vein

PVI = pulmonary vein isolation

RV = right ventricle

VT = ventricular tachycardia

highly symptomatic, with a Canadian Cardiovascular Society Severity of Atrial Fibrillation (CCS-SAF) score of 4. Medical management included metoprolol and flecainide. Her noncardiac history was significant for an elevated body mass index and rheumatoid arthritis treated with methotrexate.

DIFFERENTIAL DIAGNOSIS

On the basis of the known acute complication profile (Table 1)[1,2] of PVI ablations, the initial thought was cardiac tamponade, possibly secondary to PV perforation; however, the transesophageal echocardiogram did not identify a significant effusion.

INVESTIGATIONS

During the episode, the transesophageal echocardiogram revealed bubbles with a "snowstorm" appearance in the left ventricle (LV), right ventricle (RV), pulmonary artery, aorta, and left ventricular apex that were quickly recognized as gas emboli (Figure 2B). The electrocardiogram widened into a left bundle branch block with inferior ST-segment elevation (Figure 1B), followed by 1 episode of polymorphic ventricular tachycardia (VT) (Figure 1C).

The LV and RV were globally severely hypokinetic, suggesting probable coronary artery gas embolism. Within minutes, the wall motion abnormalities and ST-segments had normalized (Figure 1D), and the patient was weaned from pressor support.

The cryoballoon was removed, with evidence of blood in the lumen (Figure 2A).

TABLE 1 Acute Complications of Ablation Procedures

Acute Complications	RECABA Registry, %	J-AB Registry, %
Total	3.9	2.5
Phrenic nerve palsy	2.3	0.39
Cardiac tamponade	0.45	0.53
Embolism	0.1 (cerebral)	0.2 (cerebral or systemic)
Transient ST-segment elevation	0.68	N/A
Major bleeding	0.11	0.90
Other	0.22	0.48

Data from Ferrero-De-Loma-Osorio et al (the RACEBA Registry)[1] and Kusano et al (the J-AB Registry)[2] comprising a total of 64,837 cryoballoon procedures (1,741 and 63,096, respectively).
J-AB = Japanese Catheter Ablation Registry; N/A = not available; RECABA = Report of the Spanish Cryoballoon Ablation Registry.

MANAGEMENT

The procedure was immediately stopped, and further support was requested from the cardiac intensive care unit (CICU) and interventional cardiology. High-flow oxygen was administered to facilitate gas resorption, patient's head was placed in the Trendelenburg position, and norepinephrine administration was started. The patient required 1 external direct current cardioversion at 200 J for the episode of polymorphic VT.

Immediate consideration was made for cardiac catheterization to evacuate any residual gas. However, this issue resolved spontaneously because the gas dissolved with concordant clinical resolution, including ST-segment normalization, improvement in biventricular function, and weaning from inotropic support.

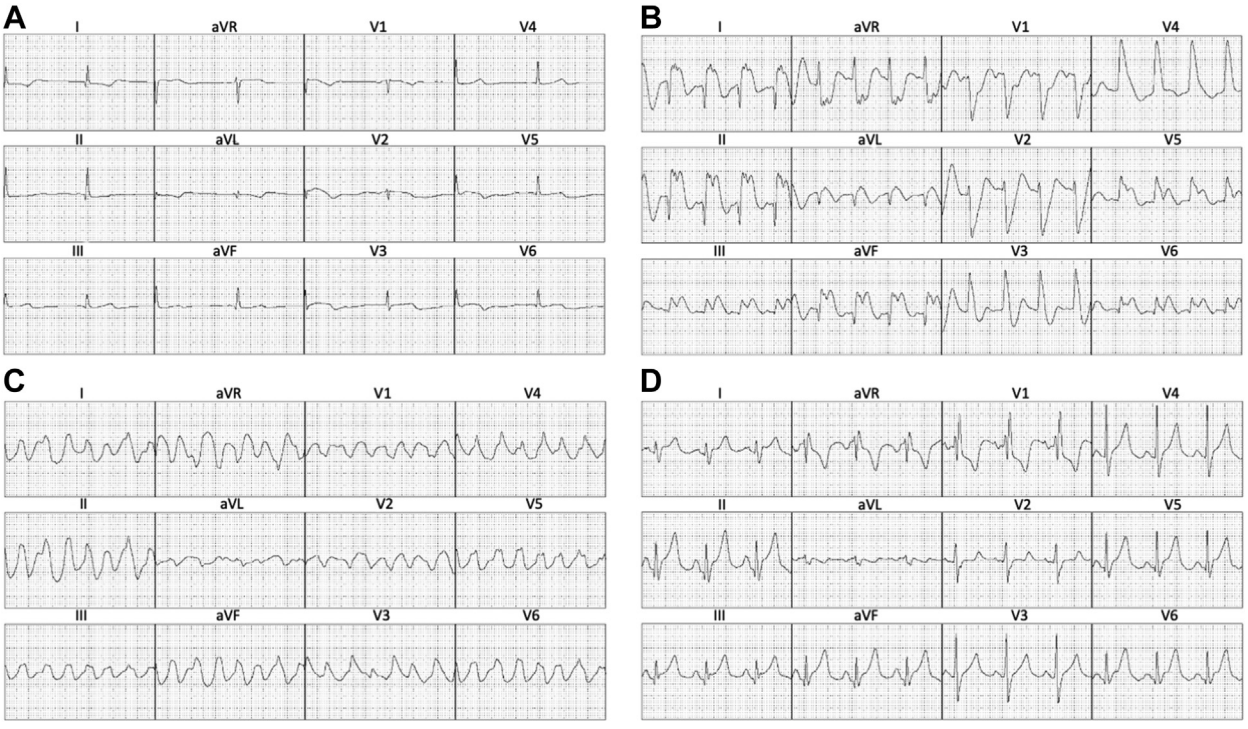
The cryoballoon was removed and showed evidence of blood within the balloon walls (Figure 2A). Medtronic, the manufacturer, was contacted to discuss the probability of a balloon breach. A Medtronic representative suggested that detection of fluid in the system would result in immediate negative pressure/vacuum in the system, but certainly the volume of the 28-mm balloon of gas would have at least escaped, should it have burst. Inspection of all our infusion lines, bags, and pumps showed no air into the system leading into the lumen of the FlexCath sheath.

The balloon was sent to Medtronic for analysis and indeed revealed a cryoballoon breach and a kink 1.7 cm proximal to the catheter tip that likely represented a fault in the structural integrity of the shaft segment.

DISCUSSION

To date, 6 double-walled cryoballoon breaches have been documented, including this account, with 1 published report. Five episodes have caused transient hypotension, and 2 have caused ventricular rhythms.[3] Fortunately, in all the reports, the patients fully recovered without any lasting complications. The hemodynamic consequences of these episodes are all in the range of minutes, likely representing the fast dissipation of nitrous oxide (N_2O) gas in the blood.[4] To our knowledge, this is the first case where gas emboli were visualized traveling in right- and left-sided cardiac chambers and, correlating the hypotension with transient ST-segment elevation and reduced systolic function, probably representing epicardial coronary artery embolizations.

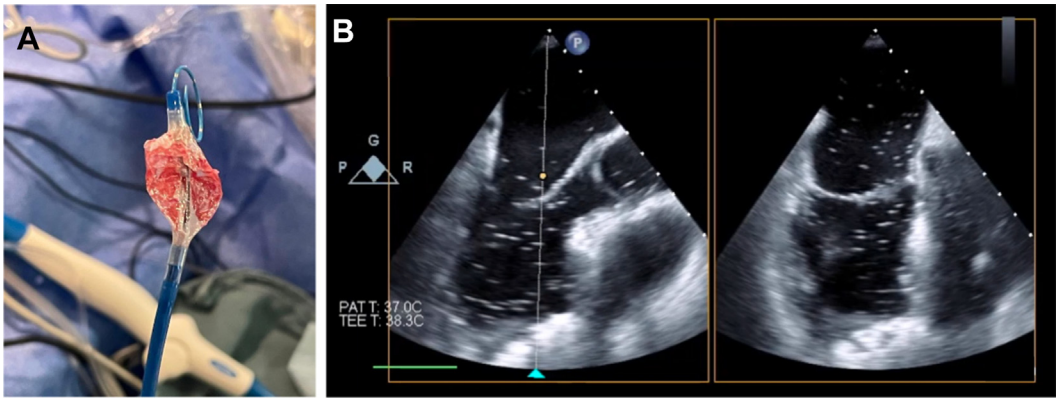
FIGURE 1 **Intraprocedural Electrocardiograms**



(A) Starting electrocardiogram showing normal sinus rhythm. (B) Widening electrocardiogram to left bundle branch block and inferior ST-segment elevation. (C) Polymorphic ventricular tachycardia. (D) Resolving ST-segment elevation with right bundle branch block.

Cryoballoon ablations are relatively safe procedures with low complication rates (Table 1). Large-scale ablation registries have documented that the most common complications are phrenic nerve injury and tamponade.[1,2] Cryoballoon wall breaches are exceedingly rare and have not been described as complications in large registry data. Cryoballoon ablations rely on the delivery of liquid N_2O by the CryoConsole that

FIGURE 2 **Breached Cryoballoon and Gas Emboli**



(A) Breached cryoballoon with intraluminal blood. (B) Intraprocedural transesophageal echocardiogram showing gas emboli traveling through the left atrium, left ventricle, and left ventricular outflow tract. G = general; P = penetration; PAT T = patient temperature; R = resolution; TEE T = transesophageal probe temperature.

TABLE 2 Signs and Treatment of Gas Embolisms

	Venous Gas Embolism	Arterial Gas Embolism
Acute clinical signs	Decrease in end-tidal CO_2 Hypoxemia Hypotension	Neurologic: seizures, focal neurologic deficits, confusion, altered level of consciousness Cardiac: arrhythmias, hypotension, ST-segment elevation, shock, MI
Treatment	Mainly supportive (oxygen, fluids, and vasopressors)	Hyperbaric oxygen once stable Supportive (oxygen, fluids, and vasopressors)
Patient position	Left lateral decubitus and Trendelenburg (unless CPR is necessary)	Supine
Prevention of further entry	Increase venous pressure Identify and terminate gas entry	Identify and terminate gas entry

Data from Muth and Shank.[5]
CPR = cardiopulmonary resuscitation; MI = myocardial infarction.

vaporizes into the balloon, thereby absorbing heat from the surrounding structures and quickly cooling its surroundings. The warmed N_2O is then vacuumed back to the console for discharge. The CryoConsole can detect any changes in flow and halt the operation, as has been the case with all the reported cases of breach.[3]

Gas emboli can have significant impact on morbidity and mortality and are differentiated as venous or arterial.[5] The consequences of these emboli have ranged from respiratory to cardiac to neurologic manifestations, and the emboli can result in cardiac arrest, potentially requiring emergency extracorporeal membrane oxygenation.[5,6] The most common reported clinical sequelae were as follows: desaturation in 34%, with a reduction in end-tidal CO_2 being the first clinical sign; neurologic changes, including seizures, in 32%; and cardiac arrest in 19%.[6] Bradycardia and hypotension are also quite common, on the basis of the previous 5 cryoballoon breaches documented.[3] It is important to recognize these potential clinical complications and initiate supportive and definitive treatment promptly (**Table 2**, Videos 1 and 2).[5] This treatment includes a high fraction of inspired oxygen, which raises the rate of gas resorption by increasing the partial pressure of oxygen in the blood, and hyperbaric oxygen therapy once the patient's condition is stabilized. Mechanical ventilation should be initiated in patients with respiratory failure, with fluids and vasopressors for hemodynamic support. Attention to neurologic symptoms is important. These symptoms may manifest as seizures or focal neurologic deficits. Manual extraction of embolized gas has been performed and can be attempted if vascular access is obtained or patient is in extremis. For patients with venous embolism, the Durant maneuver or Trendelenburg positioning is recommended, although this approach is debated in patients with arterial embolisms because it may worsen cerebral edema in neurologic injury.[5,6]

FOLLOW-UP

Fortunately, the patient did not have any lasting complications from the procedure and was discharged from the CICU the following day. Follow-up Holter monitoring at 6 months did not reveal any evidence of AF.

CONCLUSIONS

PVI ablations for AF are relatively safe procedures, with a well-established complication profile. Cryoballoon breaches are rare complications, but they have been described previously and can cause sudden hemodynamic compromise and multiorgan dysfunction. Early recognition and treatment are essential given the high morbidity and mortality of these complications.

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KEY WORDS ablation, atrial fibrillation, complication

APPENDIX For supplemental videos, please see the online version of this paper.