Hemodynamically significant iatrogenic atrial septal defects after cryoballoon ablation

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Introduction

Left atrial procedures requiring large sheaths and manipulation within the left atrium are increasingly common in electrophysiology. Iatrogenic atrial septal defects (iASD) created for these procedures are generally benign and do not require closure. In this report we describe 2 hemodynamically significant atrial septal defects (ASD) that occurred after cryoballoon ablation for pulmonary vein isolation.

Case report

Case 1

An 83-year-old woman presented with persistent atrial fibrillation, symptomatic despite rate control and intolerant of rhythm control and warfarin. Past medical history was significant for a left posterior cerebral artery stroke. Baseline transesophageal echocardiogram (TEE) demonstrated an intact interatrial septum (Figure 1). The patient was brought to the electrophysiology laboratory for planned cryoballoon pulmonary vein isolation followed by left atrial appendage (LAA) closure with the Watchman device (Boston Scientific, Marlborough, MA). A single transseptal puncture was performed at an anterior position closer to the inferior limbus with a radiofrequency (RF) needle (Bayliss Medical, Montreal, Canada) under intracardiac echocardiographic and fluoroscopic guidance. After positioning of a 12F deflectable sheath (FlexCath Advance, Medtronic, Minneapolis, MN) across the septum, a 28 mm cryoballoon (Arctic Front Advance, Minneapolis, MN) was delivered to the left atrium. Cryoballoon ablation was performed beginning with the left superior pulmonary vein, then the left inferior pulmonary vein, followed by full deflection of the sheath with the balloon catheter within the sheath, posterior rotation of the sheath to the right inferior pulmonary vein, and then sequential ablation at the right inferior, right middle, and right superior pulmonary veins. Advanced maneuvers, such as the "hockey stick" maneuver, were not used. A total of 9 cryoballoon applications were made. Continuous pressure monitoring from the tip of the cryoballoon catheter was consistent with the expected left atrial and right ventricular waveform converting to a right ventricular–only waveform during balloon inflation and positioning for all veins. Complete isolation (entrance and exit block) of all pulmonary veins was demonstrated with the use of a deflectable, multielectrode adjustable ring catheter (LASSO, Biosense-Webster, Irvine, CA) delivered through the 12F FlexCath Advance sheath. No additional sheaths were delivered to the left atrium. Left atrial dwell time to that point was 74 minutes. TEE was then performed in preparation for LAA closure. This demonstrated a tear of the atrial septum resulting in a large defect measuring up to 3 cm in diameter with bidirectional, continuous shunt, which was predominantly left to right (Figure 2). The right ventricle appeared mildly enlarged with mildly reduced function. The patient developed right atrial tachycardia and required vasopressors. After successful external cardioversion, the patient was hemodynamically stable and did not require vasopressor support. Percutaneous transcatheter closure was discussed but the patient was deemed ineligible because of the size of the defect and insufficient rims. Surgical consultation was obtained and owing to patient stability, an elective surgery was performed later during the same hospitalization. The patient underwent an atrial septal repair along with a biatrial maze, LAA ligation and excision, and a tricuspid valve repair. For persistent symptomatic atrial fibrillation, the patient underwent atrioventricular node ablation and cardiac resynchronization therapy pacemaker device implant 6 weeks later. She was doing well at subsequent outpatient follow-up office visits.

Case 2

A 63-year-old man with a history of hypertrophic cardiomyopathy status post myomectomy and LAA ligation and nonsustained ventricular tachycardia status post implantable cardioverter-defibrillator implant presented with an increasing burden of symptomatic paroxysmal atrial fibrillation despite antiarrhythmic therapy. Baseline TEE demonstrated an intact interatrial septum (Supplemental Figure). Cryoballoon ablation was performed using the same equipment and techniques as described for the first case. A total

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KEY TEACHING POINTS

- Hemodynamically significant atrial septal defects (ASD) are a known but rare complication of left atrial catheter ablation procedures.
- Cryoballoon ablation is more likely than radiofrequency ablation to result in a persistent ASD.
- Large iatrogenic ASD or even atrial septal tear may occur during cryoballoon ablation procedures, with possible mechanisms related to the size of the sheath, particular sheath maneuvers, and possibly even inflation of the cryoballoon while positioned across the septum.
- Large iatrogenic ASD may not be recognized during the procedure or in follow-up unless the atrial septum is specifically evaluated.

of 12 cryoballoon applications were performed, 2 in each of the left superior, left inferior, right middle, and right superior pulmonary veins and 4 in the right inferior pulmonary vein, including with use of the "hockey stick" maneuver. Because of persistent connection at the inferior aspect of the right inferior pulmonary vein, segmental RF ablation was performed with an 8 mm DF curve catheter (Biosense Webster, Irvine, CA) delivered through the 12F FlexCath Advance sheath. No additional sheaths were placed in the left atrium. Entrance and exit block was confirmed at all 4 pulmonary veins with the same technique described in the first case. Left atrial dwell time was 115 minutes. The patient had an uneventful postprocedural course and was discharged home. Over the following 20 months he had a stable course and 2 transthoracic echocardiograms (TTEs) were unremarkable, but the atrial septum was not thoroughly evaluated. He then developed recurrence of atrial fibrillation and a precardioversion TEE revealed a large (1.2 cm) ASD (Figure 3) with significant left-to-right shunting (Qp:Qs 1:6). The right ventricular size was mildly enlarged compared to the previous studies

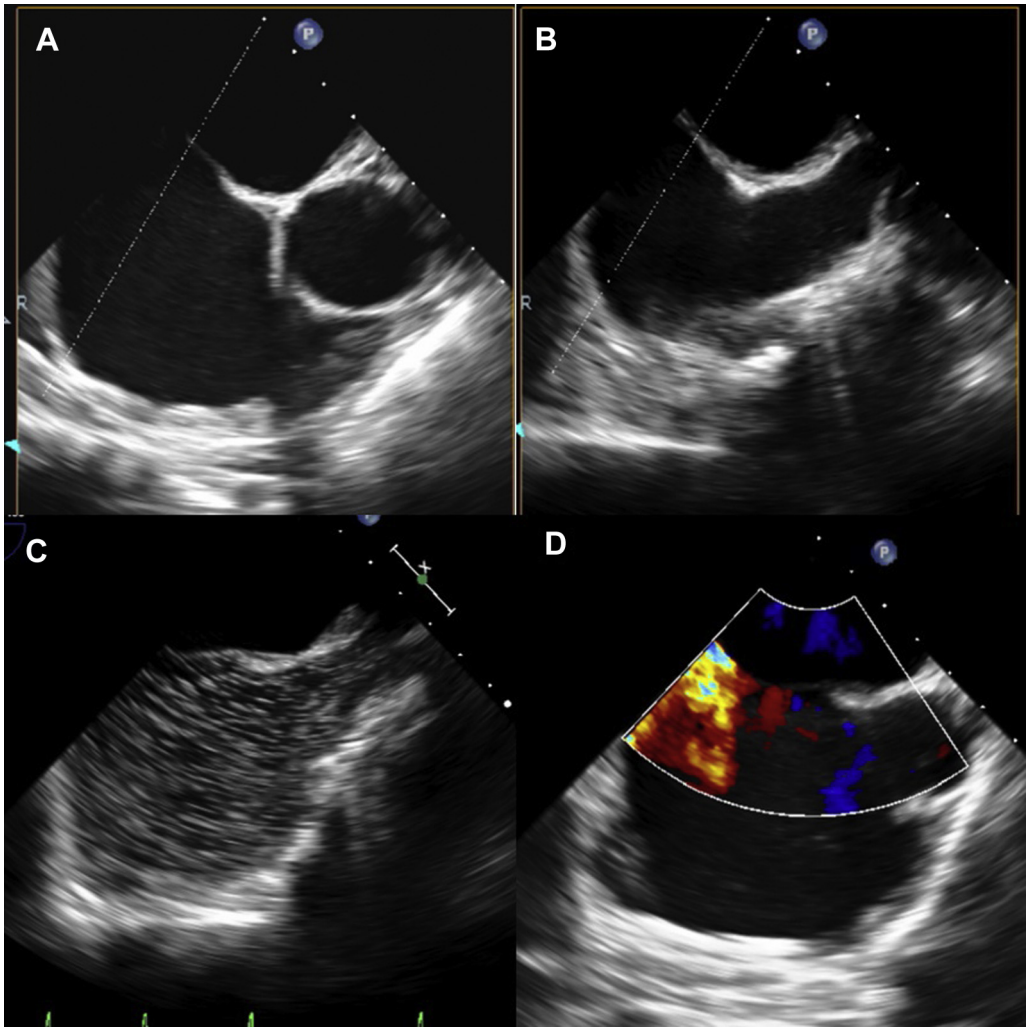

Figure 1 Baseline transesophageal echocardiogram from case 1 demonstrates an intact interatrial septum by 2-dimensional (**A, B**), agitated saline (**C**), and color imaging (**D**).

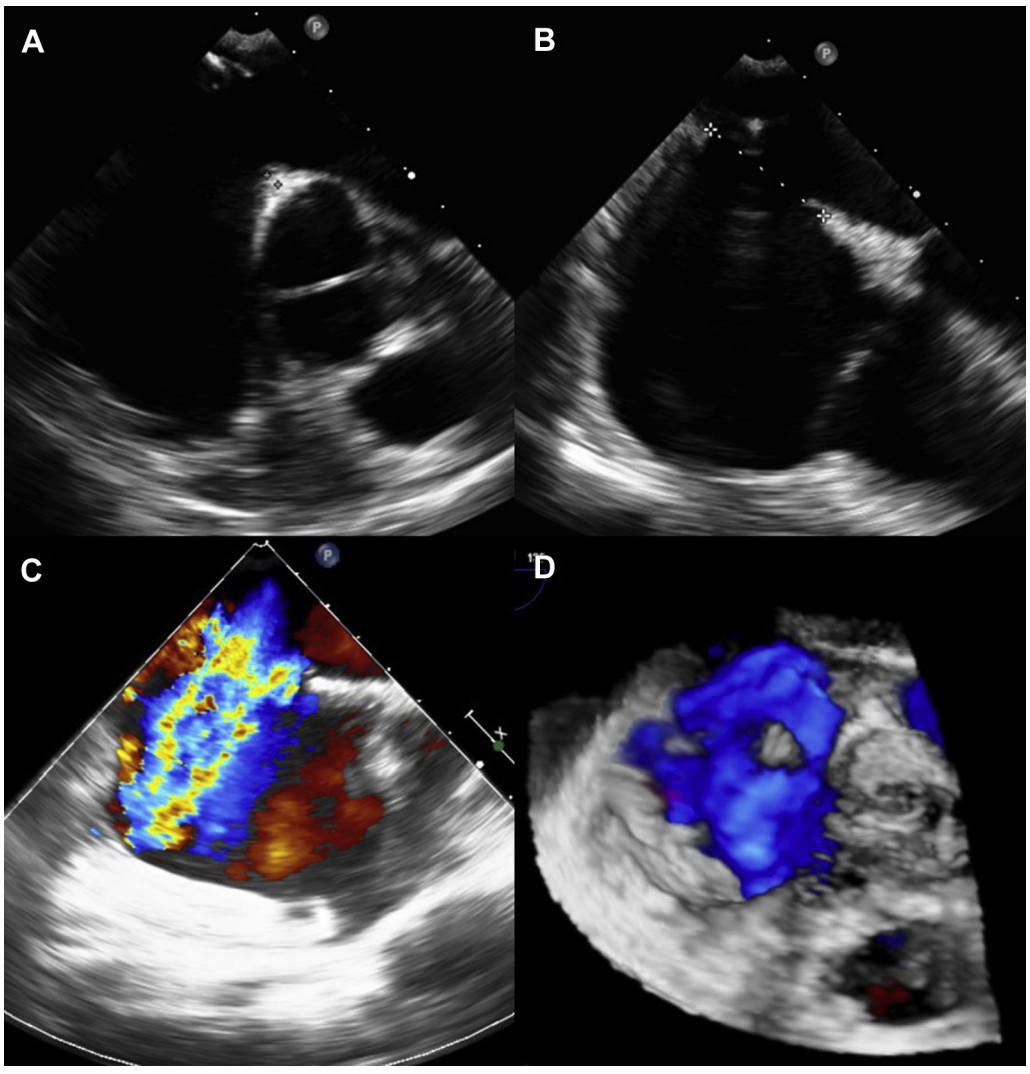

Figure 2 Intraprocedural transesophageal echocardiogram from case 1 after cryoballoon ablation demonstrates a large iatrogenic septal defect with inadequate rims (**A, B**) and large left-to-right shunt by color imaging (**C, D**).

and the systolic function was normal. Owing to the size of the defect, the patient underwent redo sternotomy and patch repair of the ASD. Unfortunately, the surgery was complicated by type 1 aortic dissection and acute left arm and abdominal ischemia. Despite left carotid–to-subclavian bypass and superior mesenteric artery stenting with dissection flap fenestration, the patient developed intractable acidosis and died.

Discussion

iASD is a known but under-recognized complication of left atrial procedures including pulmonary vein isolation. The defect usually presents with left-to-right shunt owing to the relatively higher left atrial pressure compared to the right atrial pressure but can also present with right-to-left shunt when there is underlying right heart failure or pulmonary hypertension. Several case reports and series have been published describing the incidence and clinical implications of an iASD after pulmonary vein isolation.[1–8] Within these series very few patients required closure of the iASD, suggesting that an iASD is generally benign. In the first report examining the incidence and outcome of iASD after cryoablation specifically, 4 of 13 patients had persistent iASD at 9 months and 1 required closure.[3] Cronin and colleagues[4] reported that 8 patients with iASD were identified among their cohort of 42 cryoablation patients matched with 42 patients treated with RF, who underwent TTE at 118.2 ± 40.7 days. In the largest and most recent series that looked at outcomes after cryoablation, 102 patients who underwent 1 follow-up echocardiogram were identified; the prevalence of iASD was 37% at 2.9 years and decreased over time, and none required closure.[8]

In the first case presented here, a large septal tear resulting in a hemodynamically significant iASD was incidentally identified during the procedure, after cryoballoon ablation,

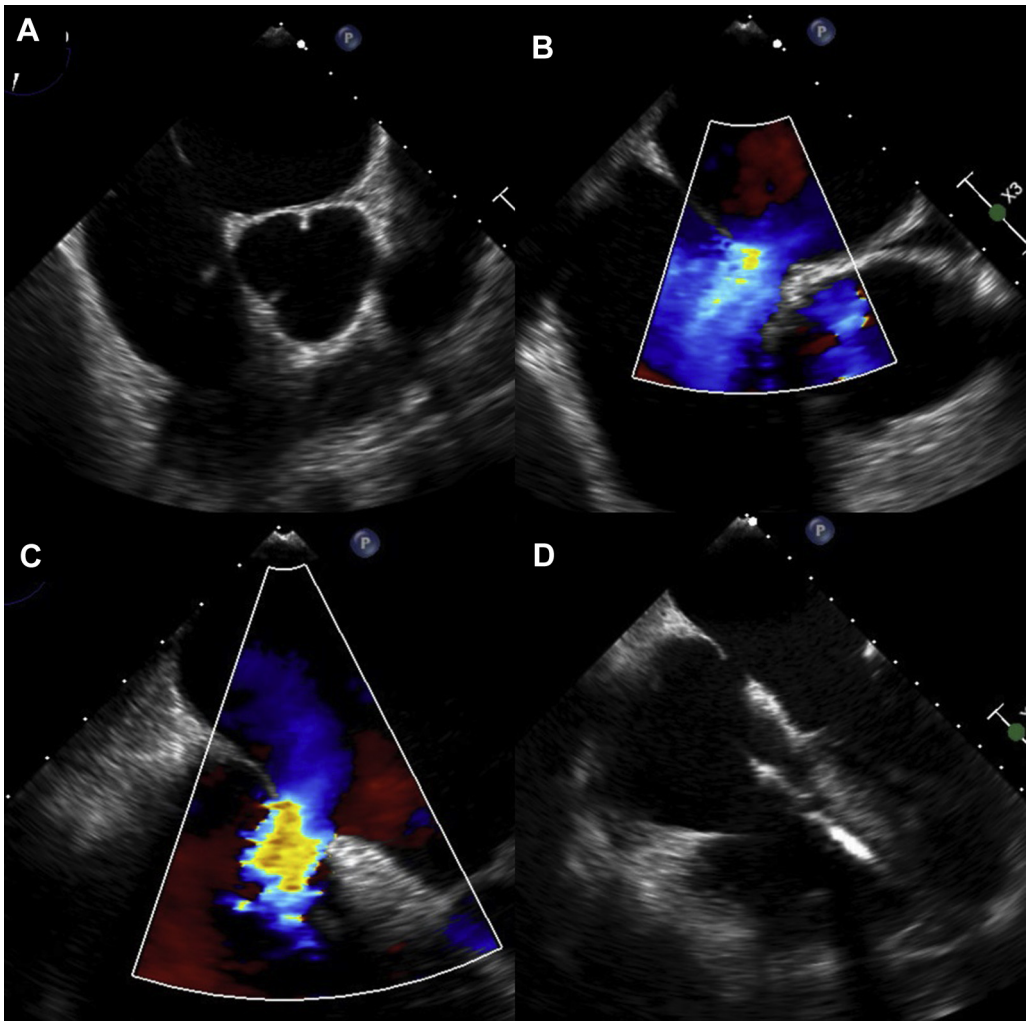

Figure 3 Follow-up transesophageal echocardiogram from case 2 (20 months after cryoballoon ablation) demonstrates a persistent iatrogenic atrial septal defect (**A**–**C**) and right ventricle enlargement (**D**).

because a TEE was performed in preparation for LAA closure. To our knowledge this is the first report of an iASD of this size (up to 3 cm) identified following cryoballoon ablation. A smaller (1.5 cm) iASD identified during cryoballoon and RF ablation was reported in a patient with arrhythmogenic right ventricular dysplasia and dilated right heart chambers who developed right-to-left shunt with acute hypoxia requiring emergent percutaneous closure of the iASD.[9] Persistent hypoxia necessitating subacute percutaneous closure of a 0.7-cm iASD in another patient with arrhythmogenic right ventricular dysplasia who underwent RF pulmonary vein isolation has also been reported.[10] Yousuf and colleagues[11] reported an iASD measuring 1.1 cm that was identified in a patient who underwent cryoablation, followed 3 months later by RF ablation, and then presented a few days later with heart failure symptoms. There have also been previous reports of a large iASD identified intraprocedurally as a result of an ASD sizing balloon[12] and during a MitraClip procedure.[13]

The second case describes a persistent chronic iASD that resulted in significant left-to-right shunt and right ventricular enlargement. The iASD was not identified on 2 follow-up TTEs because the interatrial septum was not specifically interrogated. TTE remains the preferred initial modality to evaluate for ASD but is less sensitive than TEE.[14] This is evident when comparing the reported prevalence of iASD when patients were evaluated by TEE vs TTE. Cronin and colleagues[4] evaluated patients with follow-up TTE and reported a prevalence of 16.7% after cryoballoon ablation and 2.4% after RF ablation,[4] whereas Mugnai and colleagues[5] used TEE and reported a prevalence of 22% after cryoballoon ablation and 8.5% after RF ablation.

Various predictors for the occurrence of persistent iASD have been reported. The atrial septal angle was the only predictor in a small series analyzing a cohort of patients who underwent cryoablation.[6] Lower LAA velocity was found to be predictive of iASD in a cohort of 102 patients who underwent cryoballoon ablation.[8] A single puncture with 2 sheaths vs 2 separate puncture sites has been associated with a higher incidence of iASD.[1] Cryoballoon ablation requires a larger sheath and perhaps more involved sheath manipulation than do RF ablation procedures and has been associated with a higher incidence of iASD.[4,5] Inadvertent inflation of the cryoballoon while it is positioned across the

atrial septum could result in septal tear or much larger iASD, though there was no indication that this mechanism was involved in the case presented, given the findings from continuous pressure waveform monitoring during balloon inflation and positioning.[14] The location of transseptal puncture may also predict persistence of the iASD. Rich and colleagues[15] reported significantly reduced incidence of iASD with the use of an inferior limbus location for transseptal puncture compared with the traditionally preferred fossa ovalis.

iASD after left atrial procedures are common, but they are usually small and the majority spontaneously close. However, these 2 cases illustrate that hemodynamically significant defects including large septal tears can occur. Indications for closure are the same as with congenital ASD: when the patient develops symptoms such as an embolic event or hypoxemia due to right-to-left shunting or right heart enlargement/failure due to left-to-right shunt. An iASD may not be identified by TTE, as in the second case presented. Consideration should be given to routine postprocedure assessment of the interatrial septum after transseptal procedures, including with intracardiac Doppler echocardiography during the procedure and/or with surface echocardiography and bubble study during follow-up. Further assessment with TEE is indicated if there is concern for a significant defect.

Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2018.10.001.

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