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Original Article

Transesophageal echocardiography for incremental value of Amplatezer cribriform septal occluder for percutaneous transcatheter closure of complex septal defects: Case series

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Abstract

Background: The anatomy of septal defects can be complex and morphologically unpredictable. Balloon sizing of such defects may not be feasible, and an appropriately sized commercial occluder may not be available. Therefore, percutaneous transcatheter closure of such defects can be challenging because of an increased risk of complications. In this study, we have described the efficacy and safety of transcatheter closure of complex septal defects using Amplatzer cribriform occluder devices, assessed by real time three-dimensional (RT 3D) color Doppler transesophageal echocardiography (TEE).

Methods and Results: Four complex septal defects were involved in this investigation: (1) reimplanted multiple atrial septal defects (ASD) with one device embolization; (2) postinfarction ventricular septal defect; (3) long tunnel patent foramen ovale; and (4) postoperative residual ASD. All patients underwent percutaneous transcatheter interventions due to the high risk of surgical complications, and one of the three available cribriform ASD device sizes (18 mm, 25 mm, or 35 mm) was implanted. Perioperative RT 3D TEE combined with fluoroscopy was used for monitoring during the procedure. All defects were successfully occluded by cribriform septal occluder devices using the transcatheter technique.

Conclusion: Our patients with complex septal defects were successfully treated by transcatheter closure using an Amplazter cribriform septal occluder device with careful planning based on patient presentation and close interdisciplinary collaboration. RT 3D color Doppler TEE provided precise information for the selection of the appropriate occluder device and facilitated the procedure by guiding the catheter through the often challenging patient anatomy.

Keywords: embolization of atrial septal defect occluder; long channel patent foramen ovale; percutaneous transcatheter closure of intracardiac defect; postinfarction ventricular septal defect; residual atrial septal defect repair

1. Introduction

Percutaneous transcatheter device closure of atrial septal defects (ASD) has become an effective alternative therapy to surgical repair in patients with secundum type ASD. Amplatzer ASD or ventricular septal defect (VSD) occluders were used for the closure of ASDs or VSDs, respectively.[1−6] The Amplatzer ASD or VSD occluders (Aga Medical Corporation, Plymouth, MN, USA) are self-expanding devices

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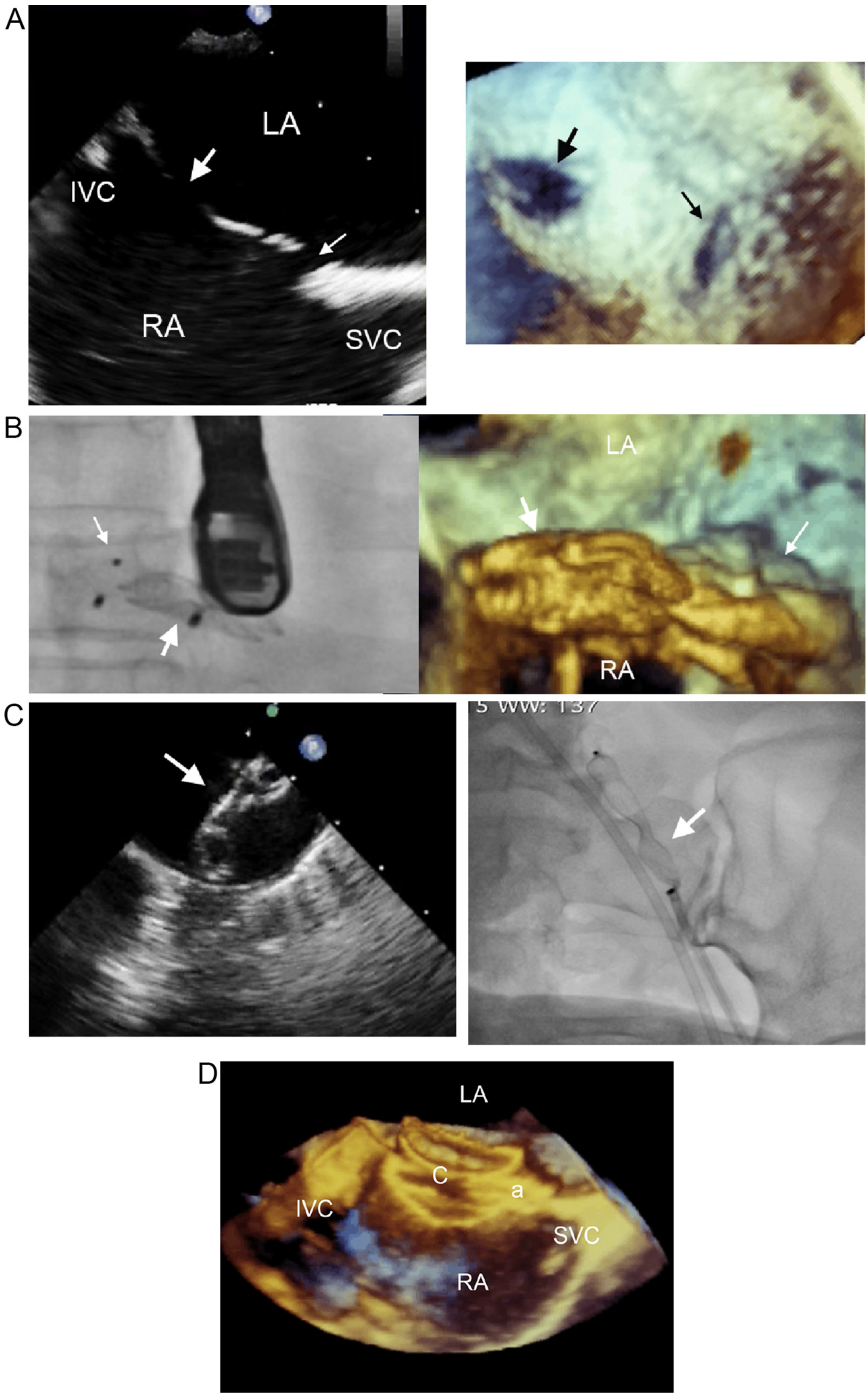

Fig 1. (A) 2D TEE in long-axis view showing two secundum ASDs (arrows). One 5-mm ASD located superiorly (small arrow) and another 8-mm ASD located inferiorly (large arrow) on the atrial septum (left frame). 3D TEE en face long-axis view demonstrating two ASDs, the superiorly located with an irregular shape (small arrow) and the inferiorly located with an ovoid shape (large arrow) with aneurysm formation (right frame). (B) Fluoroscopic image showing two occluder devices (arrows) partially overlapping after deployment (left frame). 3D TEE demonstrating more clearly the partial overlap of the two occluders (arrows) seen through fluoroscopy (right frame). (C) 2D TEE showing an occluder (arrow) dislodged into the ascending aorta (left frame). Fluoroscopic imaging demonstrating

made of nitinol. These occluders consist two umbrellas and a middle portion or "waist." However, transcather closure can be difficult in septal defects that are complex and unpredictable, thus a poor fit for conventional occluders. Herein, we have described the closure of such complex defects by using Amplatzer Multi-Fenestrated "Cribriform" septal occluders[7,8] (AGA Medical Corporation; Plymouth, Minn, USA), a product originally intended for use in the closure of multi-fenestrated ASDs. The minimal connecting waist allows the device to attain better positioning within the lesion to close the entire defect.

Two-dimension (2D) transesophageal echocardiography (TEE) with color flow and pulsed Doppler imaging has been shown to be useful in the diagnosis of septal defects.[6,9] However, certain septal defects can have a complex geometry. The dimension, location, and size of the defect viewed by conventional 2D TEE imaging alone might be inadequate; however, three-dimensional (3D) TEE can provide precise images of the shape and size of the lesion during transcatheter repair.[10−14]

Here we discuss four different cases of septal defects with complex anatomies undergoing percutaneous transcatheter interventions using different approaches.

2. Methods

2.1. Interventional closure procedure

After receiving the approval by the medical ethics committee of our hospital (CHGH-IRB:106D-02), we reviewed four patients who had complex septal defects and underwent transcatheter closure with amplatzer cribriform septal occluder from May 2013 to 2015. The transcatheter closure technique was performed under general anesthesia in a hybrid room guided by fluoroscopy and real-time (RT) 3D color Doppler TEE. All patients received peri-interventional antibiotic prophylaxis with a single dose of cefazolin (2 g) as well as aspirin (500 mg) and heparin (60 U/kg bodyweight) intravenously. The standard technique of transcatheter closure has been described in detail.[15]

2.2. TEE examination[9−14]

Perioperative 2D TEE and RT 3D TEE were performed using a 5.5-MHz new matrix array X7-2t transducer and a commercially available Philips iE33 ultrasound system after the induction of anesthesia and endotracheal intubation. RT 3D TEE was performed at the end of a comprehensive 2D TEE examination and used to assess the defect, guide the catheter intervention, assist in device selection and positioning, and check for post-procedure residual leak and the presence of any additional cardiac abnormalities (i.e., pericardial effusion or tamponade) that would affect the results. Using 3D zoom modality, the entire defect can be seen en face and the lesion can be identified. The full volume modality allows the demonstration of Doppler color flow through the defect.

2.3. Device selection

Amplatzer "Cribriform" devices[7,8] (AGA Medical Corporation, Golden Valley, MN, USA) have a thin waist and two equal large retention discs. One of the three available cribriform ASD device sizes (18 mm, 25 mm, or 35 mm) was implanted.

2.4. Case with reimplanted multiple ASD with one device embolization

Embolization of the occlusion device is one of the most disastrous complications after percutaneous closure of ASD. Device embolization usually is treated by percutaneous retrieval using a goose neck snare or surgical removal[16−18] and repair[19,20]. In this patient with device embolization, we underwent percutaneous retrieval through the femoral artery and reimplanted the cribriform occluder device to close the defect.

A 43-year-old man who was incidentally diagnosed with a secundum ASD presented for further evaluation and underwent transcatheter closure. TEE revealed two secundum-type ASDs using color Doppler, revealing left to right shunts, Qp:Qs = 1.7:1, dilated right atrium and right ventricle, and normal left and right ventricular ejection fractions. A floppy septum with two ASDs was revealed, one ASD (5 mm) located superiorly and another (8 mm) with aneurysm formation located inferiorly. The distance between the two defects was 10 mm (Fig. 1A). Two devices, 10-mm and 12-mm Amplatzer ASD occluders, were selected for closure. After implantation of the devices, those were partially overlapped, and color flow Doppler showed no residual shunt (Fig. 1B). The procedure was performed successfully without complications.

Unfortunately, before the patient was transferred to the ICU, the TEE examination revealed an embolization of the inferior 12-mm septal occluder device involving the ascending aorta (Fig. 1C). The device quickly migrated to the descending aorta, which was confirmed by fluoroscopy. Emergency retrieval of the device from the descending aorta through the femoral artery was performed using a 4-French Amplatzer goose neck snare kit (Fig. 1C). Reimplantaion of the inferior defect was discussed and planned. The large ASD occluder was first considered in order to completely overlap the anterior occluder device, which was previously implanted. However, a larger waist may not be ideal in this defect; therefore, a cribriform septal occluder with a thin waist and two large equal retention discs of 25 mm diameter was chosen to occlude the inferior defect. After

the successful retrieval of the migrated occlude (arrow) by Amplatzer goose neck snare kit through the femoral artery (right frame). (D) 3D TEE showing the complete overlap of the reimplanted cribriform occluder (C) and the ASD occluder (a) in the proper position. 2D = two-dimensional; 3D = three-dimensional; ASD = atrial septal defect; IVC = inferior vena; LA = left atrium; RA = right atrium; SVC = superior vena cava; TEE = transesophageal echocardiography.

reimplantation, TEE confirmed the cribriform septal occluder was well placed, with complete overlapping of the superior device (Fig. 1D). Emergency surgery was not necessary, and the patient was discharged 3 days after the procedure without any complications.

The cause of embolization in this case was probably the partial overlap of the two devices, which may have resulted in a counterforce between the two occluders during the cardiac cycle movement. The larger retention discs of the cribriform occluder offers a better fit, resulting in a greater stability.

2.5. Case with postinfarction VSD (PIVSD)

PIVSD is an infrequent but hazardous event. Surgical repair is the treatment of choice, yet the overall mortality rate remains high.[21]

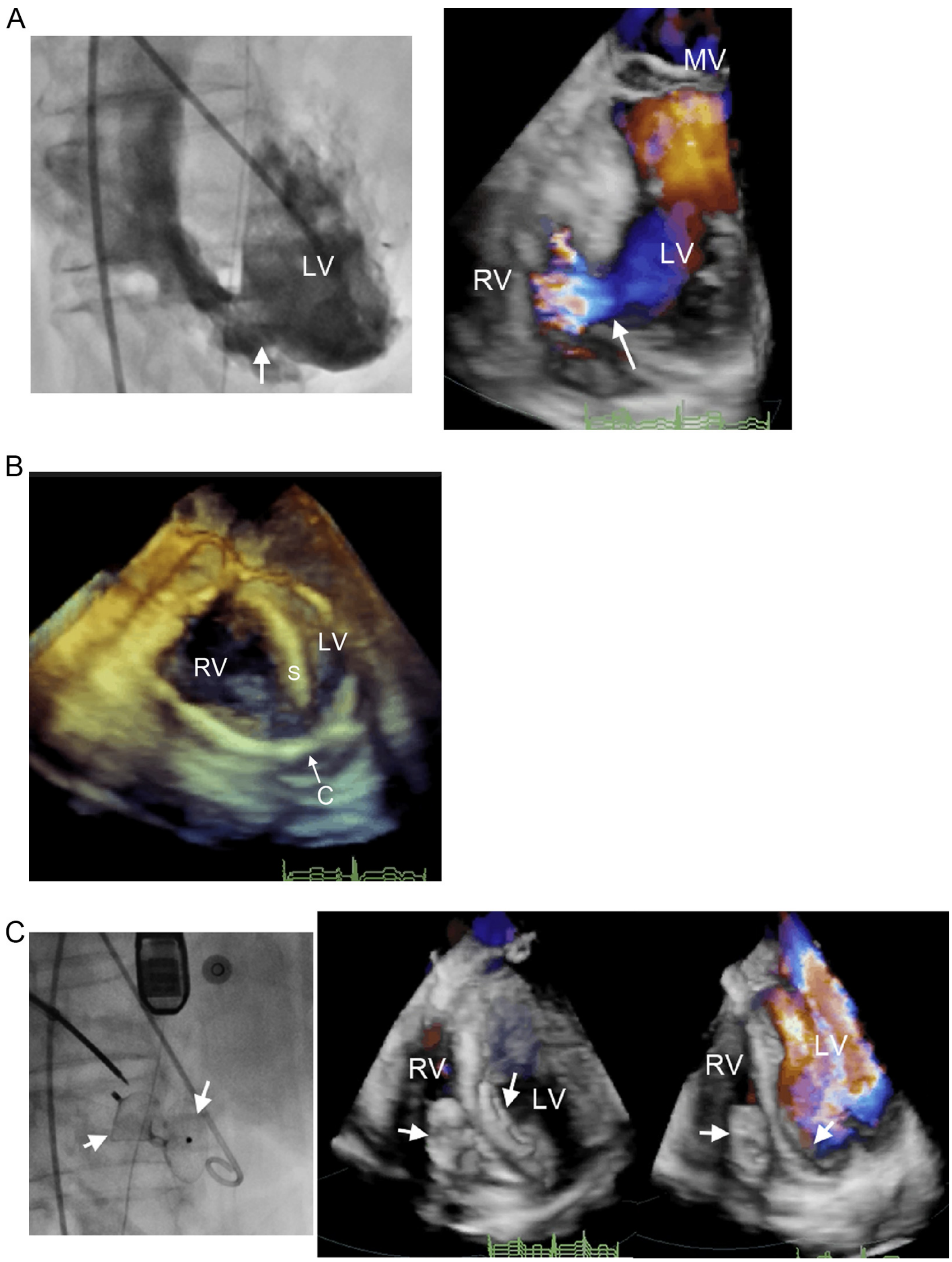

Fig 2. (A) Left ventricle angiogram (left frame) and 3D TEE with color flow Doppler (right flame) demonstrating an 8-mm defect at the apical interventricular septum (arrow). A shunt into the right ventricular cavity was noted. (B) 3D TEE demonstrating a 9-French delivery sheath (C) successfully passed through the defect of PIVSD. S = interventricular septum. (C) Fluoroscopic image (left frame) and 3D TEE with color flow Doppler (middle frame) demonstrating a cribriform septal occluder (arrow) successfully deployed at the proper position and without shunt (right frame). 3D = three-dimensional; MV = mitral valve; LV = left ventricle; RV = right ventricle; TEE = transesophageal echocardiography.

The currently available device sizes of the muscular VSD occluders[22] are usually insufficient to fully close such large and complex defects. As a result, Amplatzer ASD occluders[23] with their larger left-sided discs and waist can lead to improper device deployment of the right ventricular disc. Therefore, we selected the thin waist of the Amplatzer cribriform occluder [24]for the transcatheter closure of PIVSD.

A 93-year-old woman weighing 35 kg with a history of heart failure was admitted due to an anterior wall ST segment elevation myocardial infarction. Transthoracic echocardiography was performed revealing a defect of the interventricular septum. The low cardiac output was treated with inotropic agents and intraaortic balloon counterpulsation. The patient was not a candidate for surgical closure due to the high risk of mortality, considering her advanced age. After 2 weeks of medication, it was recommended that she undergo a transcatheter closure of the defect. The catheterization was performed in a hybrid room under intubated general anesthesia, fluoroscopic, and TEE guidance. The 3D TEE with color flow Doppler delineated a larger defect, showing 8 mm at the apical interventricular septum. Additionally, a shunt into the right ventricular cavity was also noted (Fig. 2A). Without balloon sizing, a 25-mm Amplatzer "Cribriform" multi-fenestrated septal sccluder was introduced through a 9-French transseptal sheath (AGA Medical) and successfully passed through the defect (Fig. 2B), and thereafter deployed to its proper position guided by 3D TEE with angiographic confirmation (Fig. 2C). No identifiable residual leak was observed. The patient was discharged 7 days after the procedure and later remained in a good condition for the duration of the 1 year follow-up period.

2.6. Case with concomitant long tunnel patent foramen ovale (PFO) with atrial septal aneurysm (ASA)

Certain anatomical aspects of the PFO with long tunnel make delivering the occluder device to its intended target location difficult due to inadequate disc apposition and incomplete ASA coverage. In the past, the transseptal approach utilizing the CardioSeal device was used.[25,26] In this patient with concomitant PFO with a variation of ASA, we selected a cribriform septal occluder for the closure.

A 54-year-old woman suffered two episodes of transient ischemic attack (TIA) over the past 3 months. A 2D TEE showed a PFO with a long tunnel. The length and diameter of the opening of the PFO tunnel were 12 mm and 5 mm, respectively (Fig. 3A Left, frame). The 3D TEE and color flow Doppler delineated an atrial septal aneurysm protruding into the left atrium (Fig. 3A Middle, Right frame). Considering the structural variation of the atrial septum, a cribriform occluder device was chosen to sandwich the primum and secundum septum together. Under TEE guidance, a 25-mm cribriform device was advanced and deployed with good results. TEE confirmed adequate sandwiching of the left and right atrial disks across the atrial septum, successfully occluding the PFO (Fig. 3B).

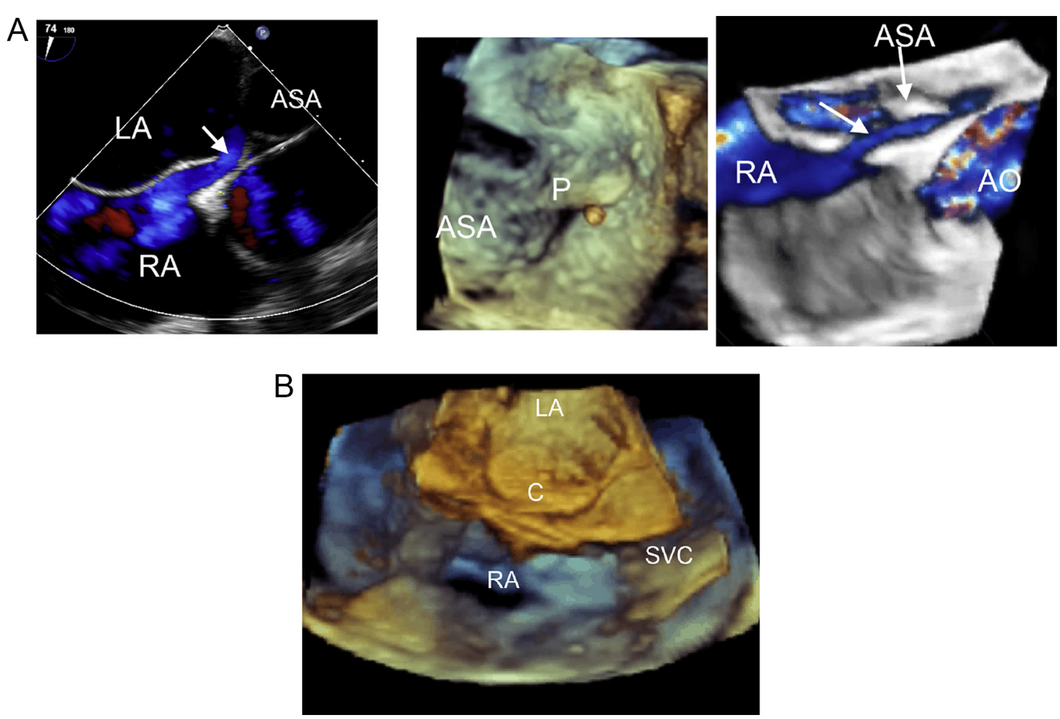

Fig 3. (A) 2D TEE showing a PFO with a long tunnel (arrow) with an ASA at the LA. The length and diameter of the opening of the PFO tunnel were 12 mm and 5 mm, respectively (left frame). 3D TEE delineated an atrial ASA protruding into the left atrium connected by a pedicle tissue (P) (middle frame). 3D TEE color flow Doppler showing a long tunnel of PFO (arrow) concomitant with a floating aneurysm (ASA). A left to right shunt (arrow) through the tunnel was noted (right frame). (B) 3D TEE confirmed adequate sandwiching of the left and right atrial disks of the cribriform occluder. (C) across the atrial septum, with complete occlusion of the PFO with long tunnel and ASA. 2D = two dimensional; 3D = three dimensional; Ao = aorta; ASA = atrial septal aneurysm; LA = left atrium; LV=left ventricle; RA = right atrium; RV = right ventricle; PFO = patent foramen ovale; SVC = superior vena cava; TEE = transesophageal echocardiography.

2.7. Case with postoperative residual ASD

Percutaneous therapy is more favorable than surgical repair of an ASD unless the defect is without adequate septal rim support or has a complex anatomy. Residual ASD following surgical patch repair is not common and usually is due to patch dehiscence or an incomplete closure of the main defect. The morphology and the location of the residual defect within the path can be complex, making transcatheter closure of such lesions challenging.[27–29]

A 47-year-old man with a known history of ASD surgical patch repair presented with recurrent TIA and exertional dyspnea. A residual ASD was diagnosed by transthoracic echocardiographic examination. He had a secundum ASD and surgical patch repair at the age of 27. TEE showed a residual atrial defect near the inferior vena cava, with an independently detached path mass (Fig. 4A, Left frame). The 3D TEE revealed the presence of a 13.5-mm, ovoid-shaped defect with redundant path tissue located in the inferior-posterior part of the atrial septum with a 3–4 mm rim of tissue between the defect and the coronary sinus (Fig. 4A, Right frame). The patient refused to undergo a repeat surgery; therefore, transcatheter closure of the residual ASD was performed under TEE guidance. An 18-mm cribriform device was selected and successfully deployed in its proper position without any residual leak (Fig. 4B).

3. Discussion

The percutaneous transcatheter technique can be an effective alternative method for the repair of cardiac septal defects. ASDs and VSDs are the most common congenital heart defects requiring procedural intervention. Transcatheter closure of secundum ASDs with a self-expandable Amplatzer septal occluder has been demonstrated to be safe and effective in both children and adults, with similar success and complication rates as surgery.[2–6] The closure of VSDs is similar to the closure of ASDs in conceptual terms; however, only the transcatheter closure of the muscular,[30] perimembranous,[31] traumatic,[32] or PIVSDs[33] are currently acceptable as an alternative to surgical closure. PIVSDs have a particularly poor prognosis with mortality rates of 94% for medically-

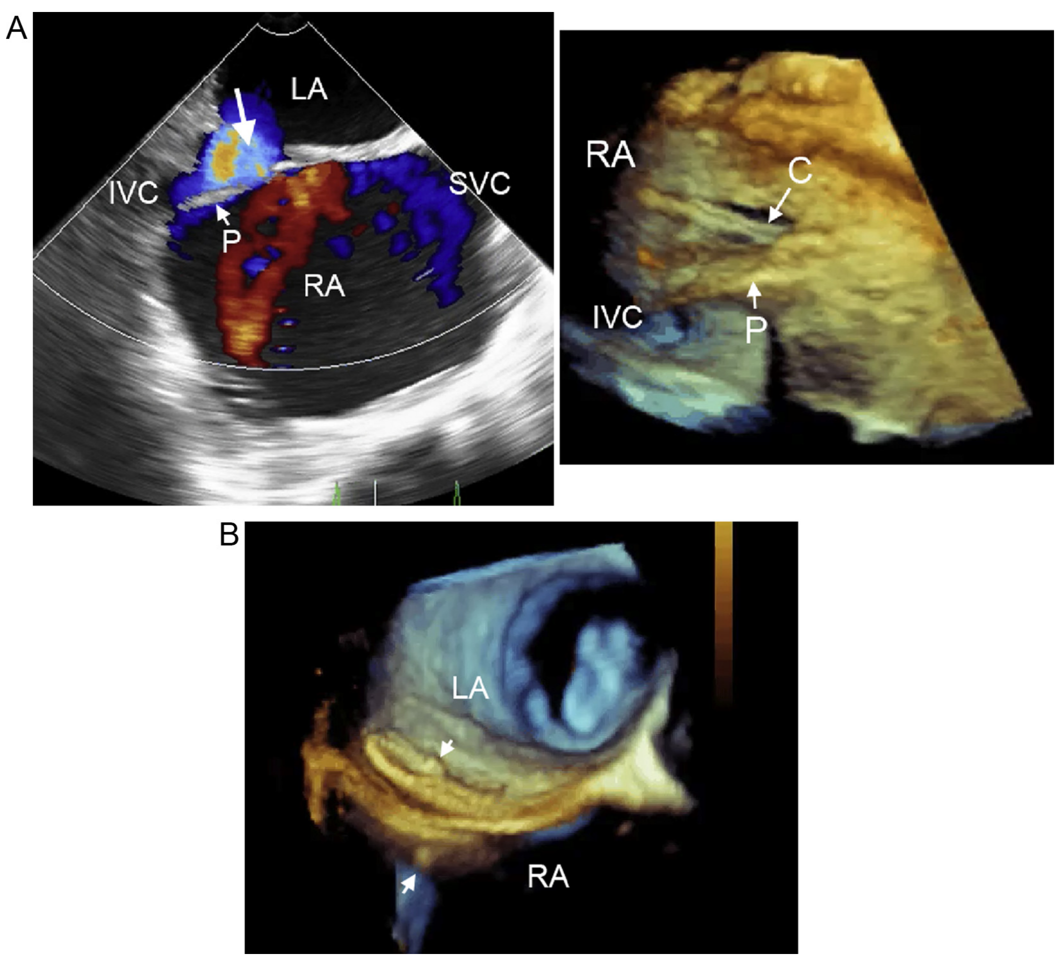

Fig 4. (A) 2D TEE showed a postoperative residual atrial septal defect (arrow) near the IVC, with an independently dehiscent path mass (P) (left frame). 3D TEE enface RA view revealed the presence of the sheath catheter (C) passed through an ovoid defect with redundant path tissue (P) located in the inferior-posterior part of the atrial septum with a 3–4 mm rim of tissue between the defect and the IVC (right frame). (B) 3D TEE showing an18-mm cribriform device (arrows) successfully deployed in its proper position without any residual leak. 2D = two dimensional; 3D = three dimensional; IVC = inferior vena cava; LA = left atrium; RA = right atrium; SVC = superior vena cava; TEE = transesophageal echocardiography.

treated patients. Survival following surgical repair is likewise quite poor with mortality rates of 47% at 30 days and 53% at 1 year post infarction.[34]

However, the anatomy of certain lesions, such as PIVSD, long tunnel PFO with ASA, and postoperative residual ASD and reimplanted multiple ASD, with one device embolization makes percutaneous intervention difficult. The currently available devices frequently are not sufficient to fully close such complex defects. Amplatzer ASD cribriform occluder specifically designed for multi-fenestrated ASD closure[35] can be a viable alternative in such complex cases. This device was selected for its rigid structural design, offering superior interatrial septal stabilization compared with other devices.

Our four complex septal defects were repaired by percutaneous transcatheter intervention with a cribriform device following very careful planning with close coordination between the different medical teams. Using 3D zoom modality, the entire septal defect was seen en face and the lesions precisely identified. The full volume modality allowed the demonstration of Doppler color flow through the communication site of the defect. Perioperative RT 3D color Doppler TEE monitoring provided accurate information and aided in determining the exact size and morphology of the defects for appropriate device selection and for facilitating the procedure.

In conclusion, we believe that in selecting patients who have a multi-fenestrated ASD, PIVSD, long tunnel PFO, and postoperative residual ASD, percutaneous transcatheter implantation of the Amplatzer "Cribriform" occluder can be a viable therapeutic option. Without the need for balloon sizing, Amplatzer "Cribriform" occluder might offer advantages for such complex septal defect closures.

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