Journal of the American College of Cardiology
© 2005 by the American College of Cardiology Foundation
Published by Elsevier Inc.

Vol. 45, No. 8, 2005
ISSN 0735-1097/05/$30.00
doi:10.1016/j.jacc.2004.12.072

Cardiac Perforation After Device Closure of Atrial Septal Defects With the Amplatzer Septal Occluder

Abhay Divekar, MBBS,* Tidimogo Gaamangwe, MSc, PEng,‡ Nasir Shaikh, MBBS,† Michael Raabe, MD,§ John Ducas, MD†

Manitoba, Canada

OBJECTIVES Amplatzer septal occluder (ASO)-associated cardiac perforation (CP) at our institution prompted this retrospective review.

BACKGROUND Cardiac perforation is a rare complication after transcatheter atrial septal defect (ASD) closure.

METHODS To identify CP after transcatheter ASD closure with ASO, cardiac events (CE) describing definite CP, hemopericardium, pericardial effusion, cardiovascular collapse, or sudden death were analyzed. Cardiac events were identified from published literature (MEDLINE), medical device regulating agencies in North America and the European Commission, and AGA Medical Corporation (Golden Valley, Minnesota). Institutional cases were reviewed. Cardiac events were defined as early (pre-discharge) or late (post-discharge).

RESULTS Twenty-nine CEs were identified. Five were excluded because findings were inconclusive for device-related CP. Ten patients were <18 years of age. Late CEs occurred in 66.6%; 25% presented weeks later (longest, three years). Three deaths were reported. Cardiac perforation occurred predominantly in the anterosuperior atrial walls and/or adjacent aorta.

CONCLUSIONS Amplatzer septal occluder-associated CP uniquely involves the anterosuperior atrial walls and adjacent aorta. Pathophysiology remains poorly understood. (J Am Coll Cardiol 2005;45: 1213–8) © 2005 by the American College of Cardiology Foundation

Transcatheter closure of atrial septal defect (ASD) is now offered as an acceptable alternative to surgery (1,2). Cardiac perforation (CP) is a unique complication of transcatheter ASD and patent foramen ovale (PFO) closure (1,3–8). Incidence varies from 0.1% to 4% for various devices (1,3). The Amplatzer septal occluder (ASO) (AGA Medical Corp., Golden Valley, Minnesota) and implantation technique have been described. The ASO-associated CP at our institution prompted retrospective review.

METHODS

Case definition. To identify CP after transcatheter ASD closure with ASO, cardiac events (CE) describing definite CP, hemopericardium, pericardial effusion, cardiovascular collapse, or sudden death were analyzed. Cardiac events were defined as early (pre-discharge) or late (post-discharge).

Case identification. Retrospective review was conducted of institutional cases including procedural transesophageal echocardiography (TEE) and catheterization data.

A literature search was conducted via MEDLINE using key words: Amplatzer, Amplatzer septal occluder, complications, perforation, erosions, cardiovascular collapse, sudden death, and hemopericardium.

During review, ASO-associated CPs were identified from the U.S. Food and Drug Administration (FDA) website prompting a search of CEs reported to other medical device regulating agencies in North America and the European Commission (websites and/or direct communication).

RESULTS

Institutional cases. A 24-year-old woman (case #29, 160 cm, 40.8 kg; Table 1) was the 13th patient undergoing device closure in March 2002. An ASD measuring 15 × 17 mm by TEE with a stretched balloon diameter (SBD) of 23 mm and deficient anterosuperior rim was closed with a 26-mm ASO using fluoroscopy and TEE. The device splayed over the aorta (Fig. 1); there was no residual shunt or impingement on cardiac structures. She was discharged the same evening on aspirin and clopidogrel. Chest radiograph was unremarkable. She was asymptomatic before collapse three days later. After cardiopulmonary resuscitation, emergent surgical exploration found a hemopericardium, and perforations were identified in the anterosuperior right atrial wall and the contiguous right posterior aortic wall. The device was removed, the ASD was closed, and the perforations were repaired. Life support was withdrawn three days later secondary to irreversible neurologic insult. Postmortem examination confirmed intraoperative findings (Fig. 2). Guidewire/delivery catheter-related injury was suggested, citing atraumatic rounded edge of the device and lack of published complications.

From the Sections of *Pediatric and †Adult Cardiology, ‡Clinical Engineering, and §Cardiovascular and Thoracic Surgery, Health Sciences Center, Winnipeg, Manitoba, Canada.

Manuscript received October 23, 2004; revised manuscript received December 18, 2004; accepted December 20, 2004.

Abbreviations and Acronyms

ASD	= atrial septal defect
ASO	= Amplatzer septal occluder
CE	= cardiac events
CP	= cardiac perforation
FDA	= Food and Drug Administration
MAUDE	= Manufacturer And User facility Device Experience database
PFO	= patent foramen ovale
SBD	= stretched balloon diameter
TEE	= transesophageal echocardiography

A 42-year-old woman (case #8, 160 cm, 56 kg; Table 1) was the 23rd patient undergoing closure. An ASD, measuring 10 mm × 13 mm by TEE with a 17-mm SBD and adequate rims was closed with a 20-mm ASO using fluoroscopy and TEE. There was no residual shunt, impingement on cardiac structures, or splaying over the aorta (Fig. 1). Aspirin and clopidogrel were prescribed. Hospital policy after this incident resulted in hospitalization for three days. Echocardiogram 24 h later showed good device position and no effusion. Three days later chest pain and shortness of breath were associated with an expanding effusion. Emergent surgical exploration found a hemopericardium, and the rim of the device was eroding through the atrial perforation. Anterosuperior right and left atrial perforations were noted at the edge of the respective retention disks (Fig. 3). The device was removed, the ASD was closed, and the perforations were repaired. Recovery was uneventful.

In both patients device integrity was maintained.

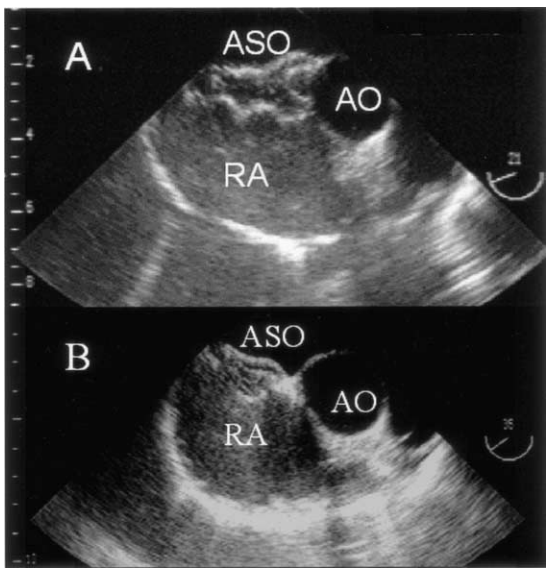

Figure 1. Transesophageal echocardiogram showing **(A)** device splayed over aortic root and **(B)** device without splaying over the aortic root. AO = aorta; ASO = Amplatzer septal occluder; RA = right atrium.

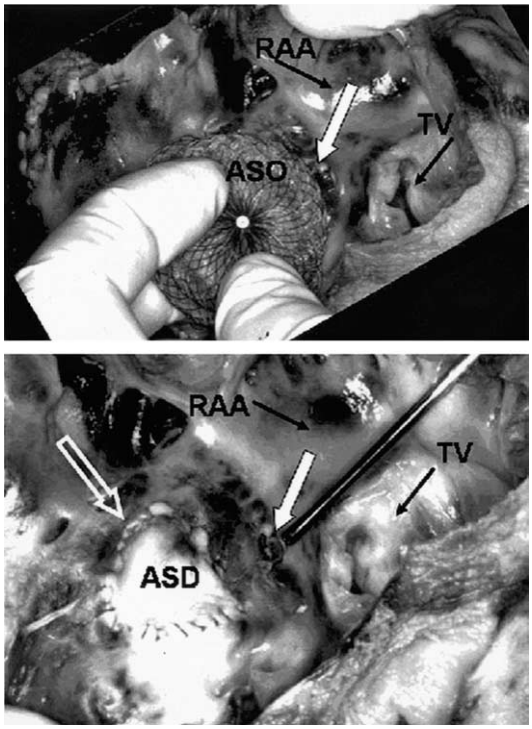

Figure 2. Postmortem illustration shows the atrial septum through the opened right atrium. The surgically closed ASD is seen **(open arrow)**. Probe shows site of right atrial perforation at the edge of the retention disk with and without device superimposition **(closed arrows)**. ASD = atrial septal defect; ASO = Amplatzer septal occluder; RAA = right atrial appendage; TV = tricuspid valve.

Analysis of reported cases. All cases reported to the manufacturer and regulating agencies and published in the literature have been accounted for and reported only once (Table 1). The U.S. FDA and Health Canada were the only agencies who had received reports of CP (Table 2). Only the U.S. FDA had free and easily accessible online information via the Manufacturer And User facility Device Experience (MAUDE) database.

Twenty-nine CEs were identified. Five were excluded because findings were inconclusive for device-related CP. All patients presented with chest pain, shortness of breath, hemodynamic collapse, or sudden death. Ten patients were <18 years of age, and 76% were women.

Among the remaining 24 CEs, 14 had defined CP and hemopericardium, 3 had defined CP and fistula formation, and 5 had hemopericardium only. The ASO size ranged from 12 to 38 mm. Relationship between SBD and ASO size is shown in Table 3. Device malposition or breach in structural integrity was not reported. Information regarding ASD morphology and technical details was not consistently available.

The CEs occurred early in 20.8% and late in 66.6% (unknown in three patients). The CEs presented 1.5 h to 3 years after intervention: 5 within 1 day, 10 within 3 days, and 6 after 3 days (3 weeks to 3 years). Good outcome was reported in 14 patients; 3 patients had neurological deficits, and 3 patients died (unknown in 4 patients).

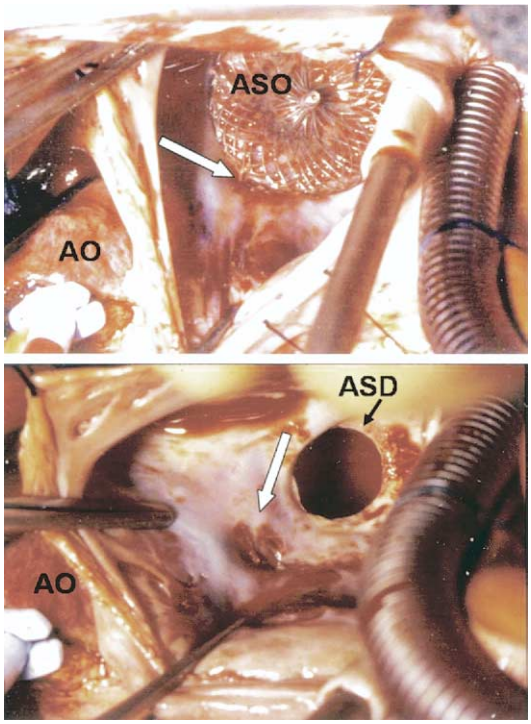

Figure 3. Intraoperative illustration shows the atrial septum through the opened right atrium before and after explanting the ASO. The right atrial perforation occurs at the edge of the retention disk **(white arrow)**. AO = aorta; ASD = atrial septal defect; ASO = Amplatzer septal occluder.

Sites of CP are shown in Table 4. All CP (except case #4) occurred in the anterosuperior atrial walls and/or adjacent aorta. All patients with CP and hemopericardium had cardiac tamponade; pericardiocentesis was performed in 10 patients. Surgical exploration was performed in 19 of 24 patients. The ASO was explanted in 15 patients and remains implanted in 7 patients (no recurrences reported).

Recent registry review suggests device oversizing and deficient anterosuperior rims as risk factors for CP and recommends abolishing intentional oversizing, stop-flow method for SBD, and careful follow-up of "high-risk" cases (1).

DISCUSSION

Technique-related CP during catheterization is inherent to the procedure, typically occurs before hospital discharge and is amenable to intervention. In contrast, device-related CP occurs after a technically adequate procedure, frequently after hospital discharge (66.6% in this review), and has the potential for a fatal outcome (1).

The rounded design and flexibility of the ASO is speculated to minimize risk of CP, even when oversized (2). An occlusion device within confines of the anteroposterior septal length is subjected to deformation forces (9). Fatigue fractures are not reported with the ASO, and the disks retain preformed shape; we therefore hypothesize that the ASO transmits deformative forces to the tissues at the point of contact between the aorta, the device, and the anterosuperior atrial walls resulting in CP.

This review shows that the anterosuperior atrial walls and/or adjacent aorta are uniquely vulnerable, the side of the larger ASO disk does not predict site of CP (Table 4), trauma over multiple cardiac cycles can damage even the thicker, more resilient aortic wall, and larger devices are not disproportionately represented (13 devices ≤25 mm, 11 devices >25 mm) in patients with CP. The CP associated with other devices also involves the free/anterosuperior atrial walls and/or adjacent aorta (3,4).

Closure of ASDs with deficient anterosuperior rims and ability to intentionally oversize by splaying over the aorta are among published merits of the ASO (2). Registry review now suggests otherwise (1). Comparison among patients receiving intentionally oversized ASOs with and without complications is necessary. Registry recommendations, although important, need validation. Several points deserve scrutiny. First, CP developed in registry patients (10 of 28) with devices sized equal to the SBD (1). Second, CP did not develop in all patients receiving intentionally oversized devices (2). Third, recurrences are not reported in patients in whom CP developed where devices remain implanted. Forth, unpredictable timing for developing CP makes careful follow-up difficult.

All postmortem reports concluded CP to be non–device-related. With information now available, we believe that our patient clearly had device-related CP. It is possible that cases #27 and #28 (Table 1) with unexplained fresh blood in the pericardial sac, may now be seen in a different light.

Prior to November 2004, there are three reports of ASO-associated perforation or fistula formation (5–7). During the same interval, the MAUDE database reports several cases. Therefore, physicians should be aware of and utilize resources other than traditional literature. Ideally an international registry and periodic end-user notification is necessary.

Study limitations. We acknowledge the limitations of this retrospective review. The MAUDE database is not intended for this purpose. The study was not designed for statistical analysis or causation but focuses on a poorly understood complication.

Informed consent should highlight device-related CP. Symptoms consistent with CP warrant prompt evaluation including urgent echocardiography. Widespread awareness may allow for timely recognition. Prompt pericardiocentesis before surgical exploration may minimize morbidity and mortality. Device removal should be considered in patients presenting with CP. Occluder size relative to anteroposterior septal dimension may be important and needs to be studied.

Understanding the pathophysiology of CP is crucial to the ongoing success of transcatheter therapy.

JACC Vol. 45, No. 8, 2005
April 19, 2005:1213–8

Table 1. Details of Cardiac Events From MAUDE Database

Case No.	IP/OP	Device Size (mm)	Stretched Balloon Diameter	Timing of Event After Procedure	Interval ECHO	Presenting Symptoms	Site of Perforation
1	ND	38	NR	2 days (30 h)	ND	Tamponade	ND
2	ND	28	NR	1 day (22 h)	ND	Tamponade and collapse	Ao
3	ND	34	NR	ND	ND	Chest pain and tamponade	LA
4	IP	18	NR	1 day (1 1/2 h)	ND	Cardiac arrest	Multiple LA
5	IP	24	NR	2 days	ND	Chest pain	RA and Ao
6	IP	20	NR	1 day (3 h)	ND	Hypotension	RA and Ao
7	IP	14	12	2 days	ND	Pre-tamponade	ND
8	IP	20	17	3 days	P	Chest pain and SOB	RA and LA
9	*IP*	*36*	*NR*	*4 h*	*NP*	*Hypotension, tachycardia, shock*	*Right upper pulmonary vein*
10	*IP*	*34*	*NR*	*2 h*	*NP*	*Chest pain*	*NA*
11	*OP*	*19*	*20*	*ND*	*ND*	*SOB, shock*	*NA*
12	*OP*	*22*	*NR*	*6 days*	*P*	*Sudden death*	*ND*
13	*OP*	*22*	*NR*	*1 month*	*P*	*Vasovagal discomfort*	*Posterior wall of LA*
14	OP	12	NR	2 days	P	Nausea vomiting pallor, hypotension, and tachycardia	RA
15	OP	22	NR	2 months	ND	Chest pain	LA
16	OP	18	NR	2 days (40 h)	P	Chest pain, dizziness, collapse	RA, Ao
17	OP	17	17	1 day	ND	Chest pain, nausea, and vomiting	LA, Ao
18	OP	26	NR	ND	P	Chest pain and syncope	LA
19	OP	24	NR	3 yrs	ND	Cardiac tamponade, CVA	Suspected erosion of Ao
20	OP	14	NR	6 months	ND	Acidosis, low output, tamponade	LA
21	OP	20	NR	ND	P	Chest pain syncope	RA
22	OP	28	NR	1 day (24 h)	ND	Chest pain, SOB, hypotension	ND
23	OP	16	NR	2 days	P	Nausea, restless, and questionable respiratory arrest	ND
24	OP	30	NR	6 months	P	Asymptomatic	Ao to LA fistula
25	OP	26	26	3 months	P	Asymptomatic	Ao to RA fistula
26	OP	26	25–26	3 weeks	ND	Hemolysis	Ao to LA fistula
27	OP	26	NR	2 days	ND	Chest discomfort, SOB, while doing homework, collapse	None
28	OP	26	NR	2 days	ND	Chest pain, SOB collapse, had a negative Holter, no history of palpitations	None
29	OP	26	23	3 days	NP	Collapsed in parking lot	RA, Ao

Cases in *italics* were excluded from analysis.

Ao = aorta; ECHO = echocardiogram; I = device remains implanted; IP = inpatient; LA = left atrium; NA = not applicable; ND = no data; NP = not performed; NR = not reported; NSAIDS = non-steroidal anti-inflammatory drugs; OP = outpatient; P = interval echo performed, no effusion, no residual shunt, stable device position, no fistula seen; R = device removed; RA = right atrium; SOB = shortness of breath.

Table 1 Continued

Tamponade	Hemopericardium	Pericardiocentesis	Device Implanted/Removed	Comments	Outcome
Y	ND	ND	R	Device looked very large and was still left behind, underwent surgery	Good
Y	Y	Y	R	Underwent surgery	Good
Y	Y	Y	R	Technically difficult procedure, underwent surgery	ND
Y	Y	N	I	Multiple laceration secondary to aggressive CPR, underwent surgical repair of lacerations	Neuro insult
Y	Y	N	R	Underwent surgery	ND
Y	Y	Y	R	Underwent surgery	Good
Pre-tamponade	Y	Y	I	Drained, hospitalized for 10 days, no reaccumulation, no surgery	Good
Y	Y	N	R	Monitored in hospital because of previous experience, underwent surgery	Good
Y	*Y*	*N*	*NA*	*The sizing balloon/guidewire likely caused perforation during manipulation for balloon sizing*	*Death*
N	*ND*	*N*	*I*	*Stable 8-mm effusion, treated with oral NSAIDS, no surgery*	*Good*
Y	*N*	*Y*	*I*	*Serous fluid, treated as pericarditis, conservative management, no surgery*	*Good*
ND	*ND*	*ND*	*NA*	*Sudden death reported, no other details were available, no surgery*	*Death*
Y	*Y*	*N*	*I*	*Car accident, hemopericardium 6 h later, underwent surgery*	*Good*
Y	Y	N	R	Emergent surgery	Good
Y	Y	Y	I	Erosion of strut, underwent surgery	ND
Y	Y	Y	R	Underwent surgery	Neuro insult
Y	Y	N	R	Insufficient superior rim, good device position, underwent surgery	Good
Y	Y	Y	R	Underwent surgery	Good
Y	Y	Y	I	Surgery delayed because of stroke, erosion suspected by AGA Medical, surgery was recommended	Neuro insult
Y	Y	N	I	Underwent surgery, buttress to the retroaortic atrial wall provided	Good
Y	Y	N	R	Underwent surgery	ND
Y	ND	Y	I	Only underwent subxiphoid exploration, no blood seen, no intervention	Good
Y	Y	Y	I	Drained 2 days, no reaccumulation, discharged on NSAIDS, no surgery	Good
NA	NA	NA	R	Initially 28 mm and then 30 mm device, questionable abrasion during initial attempt, however, no fistula at 1 month, underwent surgery	Good
NA	NA	NA	R	Device flared around aorta, RA disk concave at time of surgery, underwent surgery	Good
NA	NA	NA	R	Hemolysis, underwent surgery	Good
Y	Y	N	NA	Preliminary autopsy no cause of death, fresh blood in pericardium and left pleura	Death
Y	Y	N	NA	Sufficient rims, arrhythmia-related death on preliminary autopsy, fresh blood found in pericardium and left pleura	Death
Y	Y	N	R	Patient underwent surgery but brain death 3 days later	Death

Table 2. Complications Reported to Medical Device Regulating Agencies in North America and European Commission

Medical Device Regulating Agencies From Whom No Response Was Obtained	Medical Device Regulating Agencies Not Reporting Any Cardiac Events	Medical Device Regulating Agencies Reporting Cardiac Events
United Kingdom, Australia, Belgium, Estonia, Finland, Germany, Greece, Hungary, Iceland, Ireland, Italy, Lithuania, Malta, Netherlands, Slovenia, Spain, Sweden, Switzerland, Turkey	France, South Africa, Cyprus, Denmark, Norway, Portugal	U.S. FDA, 29 CEs were reported Health Canada, 2 CEs were reported

CE = cardiac events; FDA = Food and Drug Administration.

Table 3. Relationship of ASO Device Size to SBD

Case No.	SBD (mm)	ASO Device Size (mm)
7	12	14
8	17	20
11	20	19
17	17	17
25	26	26
26	25–26	26
29	23	26

ASO = Amplatzer septal occluder; SBD = stretched balloon diameter.

Table 4. Site of Cardiac Perforation

Site of Perforation	No. of Cases
LA alone	5
RA alone	2
AO alone	1
LA + RA	1
LA + AO	3
RA + AO	5
Suspected (no surgical confirmation)	1
None found	2
No data available	4

AO = aorta; LA = left atrium; RA = right atrium.

Acknowledgments

The authors thank Colin Phoon, MD, NYU Medical Center, New York, New York, and Reeni Soni, MD, HSC, Winnipeg, Canada, for editorial support.

Reprint requests and correspondence: Dr. Abhay Divekar, FE-241, 685 William Avenue, Winnipeg, Manitoba R3E 0Z2, Canada. E-mail: adivekar@exchange.hsc.mb.ca.

REFERENCES

1. Amin Z, Hijazi ZM, Bass JL, Cheatham JP, Hellenbrand WE, Kleinman CS. Erosion of Amplatzer septal occluder device after closure of secundum atrial septal defects: review of registry of complications and recommendations to minimize future risk. Catheter Cardiovasc Interv 2004;63:496–502.
2. Harper RW, Mottram PM, McGaw DJ. Closure of secundum atrial septal defects with the Amplatzer septal occluder device: techniques and problems. Catheter Cardiovasc Interv 2002;57:508–24.
3. Schrader R. Catheter closure of secundum ASD using "other" devices. J Interv Cardiol 2003;16:409–12.
4. Pedra CA, Pihkala J, Lee KJ, et al. Transcatheter closure of atrial septal defects using the Cardio-Seal implant. Heart 2000;84:320–6.
5. Preventza O, Sampath-Kumar S, Wasnick J, Gold JP. Late cardiac perforation following transcatheter atrial septal defect closure. Ann Thorac Surg 2004;77:1435–7.
6. Chun DS, Turrentine MW, Moustapha A, Hoyer MH. Development of aorta-to-right atrial fistula following closure of secundum atrial septal defect using the Amplatzer septal occluder. Catheter Cardiovasc Interv 2003;58:246–51.
7. Aggoun Y, Gallet B, Acar P, et al. Perforation of the aorta after percutaneous closure of an atrial septal defect with an Amplatz prosthesis, presenting with acute severe hemolysis. Arch Mal Coeur Vaiss 2002;95:479–82.
8. Ewert P, Kretschmar O, Peters B, et al. Preliminary experience with a new 18 mm Amplatzer PFO occluder for small persistent foramen ovale. Catheter Cardiovasc Interv 2003;59:518–21.
9. Latson LA. Per-catheter ASD closure. Pediatr Cardiol 1998;19:86–93.