## ORIGINAL ARTICLE
# PROCEDURAL AND SHORT-TERM RESULTS OF PERCUTANEOUS ATRIAL SEPTAL DEFECT CLOSURE IN ADOLESCENTS AND ADULTS

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**Objectives:** To evaluate the procedural and short-term results of percutaneous atrial septal defect (ASD) closure in adults.

**Methodology:** We retrospectively analysed 149 consecutive patients with a secundum ASD who underwent percutaneous closure from September 2011 to January 2021. Procedural and short-term results, including arrhythmia, device embolisation and residual shunt, were assessed at 2 days and 4 weeks and 6 months after percutaneous closure of atrial septal defect.

**Results:** The patients were 14 to 77 (37.7 ± 15.0) years old and 101 (67.8%) were female. Maximum defect size was 18.0 ± 6.3 mm measured on transoesophageal echocardiography. The device diameter used in patients who underwent closure was 21.9 ± 6.9 mm (6–38 mm). Percutaneous closure procedure success rate was 93.3%. In our study, the rates of device embolisation, arrhythmia and residual shunt were 3.6%, 1.4%, and 2.2%, respectively.

**Conclusion:** Transcatheter closure of ASDs in adults was feasible in our centre with good short-term outcome. The procedure should be performed in experienced centres by cardiologists specialised in the treatment of structural heart diseases due to potentially severe complications.

**Keywords**: Secundum atrial septal defect, percutaneous closure, complication

## INTRODUCTION

Atrial septal defect (ASD) is one of the most common congenital heart diseases in adults, accounting for 5–10% of all congenital heart diseases. ASD manifests itself as four types according to location of the ASD: the ostium secundum defect, ostium primum defect, sinus venosus defect, and coronary sinus defect.[1] Secundum ASD, which emerges as a result of an opening in the septum between the atria in the fossa ovalis region, accounts for 80% of all ASDs.[2] Most patients remain asymptomatic until an adult age due to the lack of specific clinical signs and physical examination findings. If left untreated, complications such as atrial arrhythmias, paradoxical embolism, right ventricular failure and irreversible pulmonary hypertension may develop.[2] Closing via the percutaneous method has become the first option for closing secundum ASDs in appropriate anatomies.[3] Instead of surgery, percutaneous ASD closure is preferred due to its easier procedure, less invasive nature, low cost, low complication rate, shorter hospital stay and long-term successful outcomes. In this study, we aimed to evaluate the early results of closed percutaneous secundum ASD cases in our hospital's cardiology clinic.

## METHODOLOGY

A total of 149 patients with a secundum ASD who underwent percutaneous closure in our hospital between September 2011 and January 2021 were retrospectively evaluated. Patients who did not have a rim (other than the aortic rim) that exceeded 5 mm as determined by transoesophageal echocardiogram were not included in the study. Patients with a defect diameter less than 5 mm, a defect diameter greater than 40 mm, a primum ASD, a sinus venosus ASD, a coronary sinus ASD, Eisenmenger syndrome or missing data were excluded from the study. In addition, those who were found to have additional congenital cardiac disease requiring cardiac surgery were not included. Haemodynamic measurements were not routinely performed in all patients. Hemodynamic measurements were made in patients over 65 years of age. Also, hemodynamic data were recorded in patients with a defect diameter >25-30 mm and whose pulmonary artery pressure was measured to be very high by echocardiography. Qp/qs, pulmonary capillary wedge pressure, pulmonary vascular resistance, systemic vascular resistance, pulmonary artery pressures and ventricular pressures were calculated by performing right and left heart catheterization in these patients, and closure was performed in appropriate patients. The study was

approved by the Sakarya University Faculty of Medicine Ethics Committee (Ethics Committee number:71522473/050.01.04-5995/12).

Echocardiography

All patients were evaluated by transthoracic and transoesophageal echocardiography (TEE) before the procedure. Echocardiographic procedures were performed with different devices, such as Vivid 3 (General Electric, Haifa, Israel), Vivid S70 (GE, Horten, Norway) and Philips EPIC 7 (Philips Medical Systems, Andover, MA). Patients with signs of right ventricular overload and dilation, a clear left-right shunt and a Qp/Qs>1.5 were decided to close. In addition, a decision to close was made in patients with paradoxical embolism who did not have signs of right ventricular volume overload and dilation. Upon examination, defect diameter, total septum length, the condition of the rims and their relationship with neighbouring structures (mitral and aortic valves, coronary sinuses and pulmonary veins) were evaluated. Using transoesophageal echocardiography, superior and atrioventricular rims from a mid-esophageal four-chamber view , aortic and posterior rims from a mid-esophageal aortic valve long axis view and vena cava superior and vena cava inferior rims from a bicaval view were displayed. The closure device size was determined by adding 1-4 mm to the maximum defect diameter measured by transoesophageal echocardiography according to the condition of the rims. The measurement of the total septum was made using the mid-esophageal four-chamber view. A balloon measurement was not routinely performed. A percutaneous closure procedure was performed mostly accompanied by transthoracic echocardiography, while transoesophageal echocardiography was used in several selected patients, and the success of the procedure and whether there was a residual shunt or the device was in place was evaluated. A 24-h follow-up of the patients after the procedure was performed using transthoracic echocardiography.

After the patients were informed about the percutaneous closure procedure and their informed consent was obtained, patients were taken to the catheter laboratory. Most patients underwent percutaneous closure under local anaesthesia under the guidance of transthoracic echocardiography. All patients underwent endocarditis prophylaxis and anticoagulation with 100U/kg heparin before the procedure. Some defects were evaluated for suitability for closing with a sizing balloon according to the operator's preference. Balloon sizing was performed in cases where there was insufficient data for closure on echocardiography. In addition, balloon sizing was

performed in the presence of thin and floppy rims of the atrial septal defect. In about half of the patients, the defect diameter was measured with the sizing balloon and a device 1-4 mm larger than the sizing balloon was selected. A stiff guidewire was inserted from the right femoral vein into the upper left pulmonary vein with the help of a multipurpose catheter. After that, the delivery system was advanced through the guidewire, and first the device's left atrial disc was opened in left atrium. Then, the right atrial disc was opened under the guidance of fluoroscopy and transthoracic echocardiography and the device was placed in the interatrial septum. Before the device was released from the delivery system, transthoracic echocardiography was used to check the location of the device in the interatrial septum, its placement, whether there was residual leakage in the interatrial septum, whether the device was pressing on the mitral and tricuspid valves and the aorta and whether it caused obstruction of the aortic and mitral valves. Finally, the Minnesota manoeuvre was used to evaluate whether the device was stable in the interatrial septum. After all these checks, the device was released from the delivery system. Patients were followed up in hospital for 24 h after the procedure and discharged after undergoing control echocardiography. They were asked to come for controls on the first, third, sixth and twelfth months. All patients were recommended to take clopidogrel (75 mg/d) and acetyl salicylic acid (100 mg/d) for three months. From the third to the sixth month, however, only acetyl salicylic acid (100 mg/d) was recommended.

Statistical evaluation was performed using the SPSS 16.0 program. Numerical variables were expressed as mean ± standard deviation, categorical variables as percentages.

## RESULTS

Approximately two-thirds of the patients were female (67.8%), and the mean age was $37.7 \pm 15$ years. Four of the patients had a history of cerebrovascular accident due to paradoxical embolism. Three of the patients had coexisting congenital heart disease. Two of the patients had concomitant pulmonary stenosis and one had concomitant ventricular septal defect. Percutaneous closure was performed in another session to the patient with accompanying ventricular septal defect. Patients without severe pulmonary stenosis were followed up. Demographic characteristics of the patients are presented in Table 1. Of the patients, 93.3% had a successful percutaneous closure. Defect diameter was measured with balloon sizing in 84 of the patients. The device diameter used in patients who underwent closure was $21.9 \pm 6.9$ mm

(6–38 mm). Table 2 contains data on the success of the operation and the devices used.

**Table 1: Baseline clinical characteristics of the patients with atrial septal defect**

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|---|---|
| Age (years) | 37.7 ± 15.0 |
| Gender (female), n (%) | 101 (67.8) |
| Hypertension, n (%) | 13 (8.7) |
| Diabetes mellitus, n (%) | 3 (2.0) |
| Coronary artery disease, n (%) | 5 (3.4) |
| Cerebrovascular accident, n (%) | 4 (2.7) |
| Coexisting congenital heart diseases, n (%) | 3 (2.0) |

**Table 2: Procedural data for the percutaneous closure of atrial septal defect**

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|---|---|
| Procedural success, n (%) | 139 (93.3) |
| Balloon use, n (%) | 84 (57.4) |
| Defect size (mm) | 18.0 ± 6.3 |
| Device diameter (mm) | 21.7 ± 6.9 |

Device embolism was observed in five patients. In these patients, three of the devices were embolised to the pulmonary artery, while two were embolised to the aorta. Three device embolisms were observed during the procedure, whereas there were two device embolisms over the course of the 24-h post-procedural monitoring. One of the devices that fell into the aorta during the procedure was recovered by the percutaneous method, while the other was removed by a surgical method. One of the three devices embolised the pulmonary artery during the procedure, and the other two were found to be embolised during the 24-h monitoring. Patients with device embolism in the pulmonary artery were referred to surgery. Only one of the defects in patients in whom devices embolized was treated with the percutaneous method. Atrial fibrillation developed in two patients during the procedure. Arrhythmias resolved with medical cardioversion. In addition, three patients with a residual shunt were observed to have lost it during follow-up. The complications associated with percutaneous closure are presented in Table 3.

**Table 3: Periprocedural complications after percutaneous closure of the atrial septal defect**

| | |
|---|---|
| Arrhythmia, n (%) | 2 (1.4) |
| Device embolisation, n (%) | 5 (3.6) |
| Aorta, n (%) | 2 (1.4) |
| Pulmonary artery, n (%) | 3 (2.2) |
| Residual shunt, n (%) | 3 (2.2) |

## DISCUSSION

This retrospective study showed a high success rate with very low complications for percutaneous ASD closure in a single center.

In the literature, the success rate of percutaneous ASD closure is above 90%.[4-6] In a study of patients of similar average age and device diameter, the procedure success was found to be 94.2%.[7] In our study, the success rate was 93.3%, compatible with the literature.

One of the most important complications of percutaneous closure is device embolisation. Its incidence can range from 0.5% to 3.5%.[8,9] Although it may occur at a later time, most device embolisms are observed within the first 24 h. There are many risk factors associated with device embolisation, which can be grouped under four headings: defect-related, device-related, operator-related and related to acute changes in intracardiac pressure due to physical strain. A wide defect, insufficient rims, the presence of a floppy interatrial septum and a defect not in a central location are factors related to the defect. Operator-related factors include improper placement of the device or insufficient experience. Device-related factors include large devices, small devices or type of device. Finally, physical strain, such as coughing and straining, can lead to acute changes in intracardiac pressure, causing embolisation.[10] Percutaneous closure devices most often embolise to the main pulmonary artery.[11] Although they may be asymptomatic, symptoms of cough and shortness of breath may be seen.[11-12] It is recommended to remove the embolism immediately, as the device embolism can cause bleeding obstruction and erosion in the pulmonary artery.[13]

There is no standard treatment approach for device embolism; it may vary depending on the location of the dislodged device, the experience of the interventional cardiologist, the laboratory materials and time. Basic treatment options include endovascular and surgical methods.[8] Catheter techniques, such as a gooseneck snare, a basket catheter and a forceps biopsy catheter, can be used to retrieve the device. If the embolised device cannot be retrieved, surgery is needed. If the device is very large and there are floppy rims, then surgery should be considered.[8] In addition, surgery should also be considered in case of embolisms that occur in the first 24 h after successful instalment or later since the heparin effect may be lost and thrombus may occur. Percutaneous ASD closure devices can intracardiacally embolise the right atrium, right ventricle, left atrium or left ventricle, as well as

embolise the arcus aorta or abdominal aorta by passing into systemic circulation.[14-18]

In a previous study of a series of 15 patients in which the devices were embolised or misplaced, five of the embolised devices were retrieved using catheter techniques, while 10 of them were surgically removed.[8] In a study conducted by Levi et al., 21 of 3821 patients had device embolism, and 15 of the devices were retrieved by transcatheter approach and six by surgical method.[9] In our study, two of the five embolisms among our patients had embolisation 24 h after the procedure, and another two of them had an embolism that could not be retrieved by the transcatheter method; thus, surgery was necessitated to retrieve them. In one patient, the device was successfully retrieved by the transcatheter method. In our study, a slightly higher rate was found than in the literature. Since we performed ASD closure under the guidance of transthoracic echocardiography, we may have had a higher incidence of device embolism. The fact that one of our patients had a defect diameter of greater than 30 mm and two had floppy rims may explain our slightly higher device embolism rate.

One of the common complications in the treatment of percutaneous ASD closure is arrhythmias, with supraventricular arrhythmia and atrial fibrillation being the most common types. These arrhythmias are associated with increased age and diameter of the left atrium. It has been reported that the incidence of arrhythmia can be up to 5–10% during the procedure and during follow-up.[19-23] In our study, atrial fibrillation was observed in two (1.4%) patients and was found to be similar to the literature.

Residual shunt rates after percutaneous closure can reach 19–21.4%.[24,25] In our study, the residual shunt rate was found to be 2.6%, which is low compared to previous studies. We performed percutaneous closure mostly under the guidance of transthoracic echocardiography. Therefore, we may have missed residual shunts at a clinically insignificant level.

**Limitations of the study:** The retrospective research design and the small number of patients are the most important limitations of our study. Also, patients have not been evaluated with intraoperative TEE. In addition, since there was no comparison with surgery, it was not possible to assess whether the studied technique was superior to surgery. Furthermore, the inability to compare between different closing devices provides another limitation to our study. As a final limitation, examinations were made at an early period and lacked along follow-up period after closing occurred, which led to the inability to evaluate late complications that may have taken place, such as device erosion and valve deficiencies.

## CONCLUSION

Transcatheter closure of ASDs in adults was feasible in our center, with good short-term outcome. The procedure should be performed in experienced centres by cardiologists specialised in the treatment of structural heart diseases due to potentially severe complications.

## AUTHORS' CONTRIBUTION

YC, IK, MA and MTA: Concept and design, data acquisition, interpretation, drafting, final approval, and agree to be accountable for all aspects of the work. ET, HK, and RA: Data acquisition, interpretation, drafting, final approval and agree to be accountable for all aspects of the work.

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## REFERENCES

1. Therrien J, Webb GD. Congenital heart disease in adults. In: Braunwald E, Zipes DP, Libby P, editors. Heart disease: a textbook of cardiovascular medicine. 6th ed. Philadelphia: W. B. Saunders; 2001. p. 1592-621.

2. Stout KK, Daniels CJ, Aboulhosn JA, Bozkurt B, Broburg CS, Colman JM. et al. 2018 AHA/ACC Guideline for the management of adults with congenital heart disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. J Am Coll Cardiol. 2019;73:81.

3. Baumgartner H, De Backer J, Babu-Narayan SV, Budts W, Chessa M, Diller GP, et al. ESC guidelines for the management of adult congenital heart disease: The task force for the management of adult congenital heart disease of the European Society of Cardiology (ESC). Eur Heart J. 2020;41:4153-4.

4. Haas NA, Soetemann DB, Ates I, Baspinar O, Ditkivskyy I, Duke C, et al. Closure of Secundum Atrial Septal Defects by Using the Occlutech Occluder Devices in More Than 1300 Patients: The IRFACODE Project: A Retrospective Case Series. Catheter Cardiovasc Interv. 2016; 88:571-81.

5. Villablanca PA, Briston DA, Rodés-Cabau J, Briceno DF, Rao G, Aljoudi M, et al. Treatment options for the closure of secundum atrial septal defects: A systematic review and meta-analysis. Int J Cardiol. 2017;241:149-55.

6. Turner DR, Owada CY, Sang Jr CJ, Khan M, Lim DS. Closure of Secundum Atrial Septal Defects With the AMPLATZER Septal Occluder: A Prospective, Multicenter, Post-Approval Study. Circ Cardiovasc Interv. 2017;10:e004212.

7. Ergene O, Nazlı C, Kacabaş U, Duygu H, Eren NK, Akyıldız Zİ, ve ark. Sekundum atrial septal defektlerin perkütan yaklaşımla kapatılması işlemi: Tersiyer bir merkezin deneyimi. Dicle Tip Derg. 2012; 39:97-101.

8. Chessa M, Carminati M, Butera G, Bini RM, Drago M, Rosti L, et al. Early and late complications associated with transcatheter occlusion of secundum atrial septal defect. J Am Coll Cardiol. 2002; 39:1061-5.

9. Levi DS, Moore JW. Embolization and retrieval of the Amplatzer septal occluder. Catheter Cardiovasc Interv. 2004;61:543-7.

10. Moore J, Hegde S, El-Said H, Beekman R 3rd, Benson L, Bergersen L, et al. ACC IMPACT Steering Committee. Transcatheter device closure of atrial septal defects: a safety review. JACC Cardiovasc Interv. 2013;6:433-42.

11. Engin B, Canbay C, Nişli K, Bilge AK, Umman B. Late embolization of an atrial septal defect closure device into the main pulmonary artery Anatol J Cardiol. 2020; 24:113-5

12. Manolis AS. Percutaneous retrieval of a dislodged Amplatzer septal occluder device from the pulmonary artery with sole use of a snare and device lassoing. Hellenic J Cardiol. 2018; 59:57-9.

13. Chiappini B, Gregorini R, Di Eusanio M, Ciocca M, Villani C, Minuti U, et al. Embolization of an Amplatzer atrial septal closure device to the pulmonary artery. J Card Surg. 2008;23:164-7.

14. Hierlmeier BJ, Ostrovsky G, Zarth M. Embolization of an Atrial Septal Defect Occluder Device Into the Left Ventricle. Cureus. 2020;12:e11417.

15. Koussayer S, Mousa A, Elkalla MA, Alaujan R, Khalil B. Conservative management of asymptomatic lately embolized amplatzer atrial septal occluder device to the supraceliac abdominal aorta: case report and the literature review. Radiol Case Rep. 2021;16:1912-8.

16. Ramalingam R, Patil S, Setty N, Kharge J, Puttegowda B, Rachaiah JM, et al. Tough, but not impossible-Retrieval of large atrial septal occluder devices embolized to left atrium. Interv Med Appl Sci. 2017;9:42-6.

17. Nath RK, Pandit N. Asymptomatic late embolization of Amplatzer septal occluder device. Indian Heart J. 2017; 69:338-340.

18. Katta N, Gautam S, Webel R. Successful percutaneous retrieval of embolized septal occluder device from aortic arch and placement of a newer septal occluder device in combined procedure. Case Rep Cardiol. 2016; 2016:1032801.

19. Evertz R, Reinders M, Houck C, Ten Cate T, Duijnhouwer AL, Beukema R, et al. Atrial fibrillation in patients with an atrial septal defect in a single centre cohort during a long clinical follow-up: its association with closure and outcome of therapy. Open Heart. 2020; 7:e001298.

20. Kim MS, Klein AJ, Carroll JD. Transcatheter closure of intracardiac defects in adults. J Interv Cardiol. 2007;20:524-45.

21. Spies C, Khandelwal A, Timmermanns I, Schräder R. Incidence of atrial fibrillation following transcatheter closure of atrial septal defects in adults. Am J Cardiol. 2008;102:902-6.

22. O'Neill L, Floyd CN, Sim I, Whitaker J, Mukherjee R, O'Hare D, et al. Percutaneous secundum atrial septal defect closure for the treatment of atrial arrhythmia in the adult: A meta-analysis. Int J Cardiol. 2020;321:104-12.

23. Johnson JN, Marquardt ML, Ackerman MJ, Asirvatham SJ, Reeder GS, Cabalka AK, et al. Electrocardiographic changes and arrhythmias following percutaneous atrial septal defect and patent foramen ovale device closure. Catheter Cardiovasc Interv. 2011;78:254-61.

24. Wang JK, Tsai SK, Wu MH, Lin MT, Lue HC. Short- and intermediate-term results of transcatheter closure of atrial septal defect with the Amplatzer Septal Occluder. Am Heart J. 2004;148:511-7.

25. Yang MC, Wu JR. Recent review of transcatheter closure of atrial septal defect. Kaohsiung J Med Sci. 2018;34:363-9.

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