**INTRODUCTION**

Atrial Septal Defect (ASD) is a direct communication between the heart's atria, that cause shunting from the systemic to the pulmonary circulation. ASD is the second most common congenital heart disease worldwide, with a prevalence of 1.44 per 1000 births, accounting for approximately 15.37% of all congenital heart disease cases. ASD is classified based on its location and morphology, with the secundum ASD being the most common at 75% of cases, primum ASD at 20%, and the remainder being sinus venosus defects. The majority of secundum and primum ASD cases occur more frequently in female patients. ASD is tightly linked to mutations in cardiac transcription factor genes, with higher risk if there is a family history of congenital heart disease, particularly among siblings. The extent of shunting and blood flow through the ASD is determined by factors such as defect size, ventricular compliance, and vascular resistance. Often, there is left-to-right shunting due to the lower compliance of the right ventricle, leading to increased volume and enlargement of the right ventricle (RVE). ASDs, in general, tend to close spontaneously during a child's development, although large defects can impact hemodynamic stability. The chance for ASD closure in children ranges from 4 to 96%, depending on the size of the defect. Smaller defects, less than 3mm, should close spontaneously during the first year of life. Moderate ASDs, with sizes ranging from 3 to 8mm, show closure rates of approximately 4-37.5% by the age of 1.5 years, while defects larger than 8mm often struggle to close spontaneously. Early ASD diagnosis increases the possibility of higher closure rates. Depending on the degree of right heart failure and/or pulmonary vascular disturbances, ASD in children can be symptomatic or asymptomatic. Hemodynamic evaluation of the patient significantly influences the management strategy, including the patient's functional status, changes in right atrium and ventricle volumes, and the degree of shunting. ASD closure via transcatheter or surgery may be considered for patients with ASD diameter more than 5mm evidence of RVE, and/or a left-to-right shunting between Qp:Qs > 1.5:1.

Transesophageal echocardiography (TEE) is required for a single ASD case to confirm ASD type and size, and to identify any associated cardiac anomalies or complications.

**CASE REPORT**

**Atrial septal defect occluder devices and embolization – a case series**

Yuletta Adny Ambarsari1*, Tandean Tommy Novenanto2, Dicky Panditatwa Susantya2, Supomo Supomo1, Haryo Aribowo1, Yunanto Kurnia1, Ihsanul Amal1, Irawan Satriotomo3

**ABSTRACT**

**Introduction:** Atrial Septal Defect (ASD) secundum is a commonly occurring congenital heart disease. Patients with unstable hemodynamic may require closure, which can be accomplished either percutaneous transcatheter or an atrial septal occluder (ASO) device or open surgery. Closure using an occluder carries the risk of device embolization (DE).

**Case Presentation:** This case series presents two patients who had dislodgement after ASD closure using ASO. The demographic data, comorbidities, surgical details, and follow-up results are all summarized. A 9-year-old girl and a 12-year-old boy admitted to our centre. The girl echocardiography evaluation revealed dislodgment of ASD occluder in a large secundum ASD, right upper PV blockage, and a high chance of pulmonary hypertension (PH). While the boy showed the occluder device that was misplaced and positioned in the right ventricle. A secundum ASD with a left to right shunt and moderate TR with a peak pressure gradient of 21.5mmHg were also found. During the procedure, we discovered that the girl had an occluder in the superior rim of ASD II 3x2 cm, which was dislodged towards the lower right PV, above the mitral valve, and the posterior occluder leaflet was removed by replacing a section of the rim. We discovered a secundum ASD with a dimension of 2x1 cm on the boy. The occluder was found behind the anterior cusp of the tricuspid valve. The retrieved occluder device appeared intact, and the tricuspid valve was injured, but no rupture.

**Conclusion:** The occurrence of ASO migration is uncommon, necessitating further surgery for device removal, closure of the remaining defect, and ensure there is no cardiac erosion or rupture. Surgery can also alleviate symptoms including shortness of breath and palpitations.

**Keywords:** atrial septal defect, atrial septal occluder, device embolization, device dislodgment.

evaluate the rim size and the possibility of transcatheter closure. For patients with fenestrated ASD or inadequate rims, surgical closure is recommended. Additionally, evaluating the possibility of mitral or tricuspid valve lesions is a consideration before surgical intervention. Transcatheter ASD closure can be performed using an atrial septal occluder, such as the Amplatzer Septal Occluder (ASO), Amplatzer Cribiform, or Gore Cardioform Septal Occluder.\(^4\)\(^8\)

ASO is becoming more popular since it is easier to deploy and capable of closing larger ASDs. The appropriate device sizing occluder, the use of TEE for imaging guidance, and the ability to reposition the device before releasing the screw, since these factors all have a major impact on ASD closure success. However, there are some risk associated with atrial septal occluder placement, such as cardiac erosion or perforation, device embolization (DE), thromboembolism, transient ischemic attacks or strokes, pericardial effusion, valve damage/regurgitation, arrhythmias, and conduction abnormalities.\(^8\)\(^9\)

Device embolization, also known as occluder dislodgment, rarely occurs but can be fatal. This usually happens in the presence of a large defect or insufficient rims. Device migration can occur during the procedure or after postoperative, often requiring reoperation for device removal and reimplantation or closure with a patch, which slightly increases the risk for the patient.\(^9\)\(^10\) This study reports occurrences of occluder dislodgment in two patients aged 9 and 12 years, as mentioned earlier. This is a rare complication following transcatheter ASO placement.

**CASE PRESENTATION**

**Cases 1**

A 9-year-old girl admitted to our tertiary hospital with a complaint of shortness of breath. She had a history of atrial septal occluder device placement approximately three years ago and had no issues since then. On physical examination, the patient appeared healthy with a weight of 33.2 kg and a height of 129 cm. Her heart rate was 112 beats/min, respiratory rate was 32 breaths/min, and oxygen saturation was 98% in room air. Cardiac examination revealed a normal S1 heart sound, while the S2 heart sound had an intermittent split, and no heart murmur was detected. A chest X-ray showed the presence of an occluder device at the intra-atrial septum. Further echocardiography indicated that ASD occluder device was misaligned, with the anterior rim not fully clamped (retro-aortic position) and a residual ASD measuring 2 cm with a left-to-right shunt (Figure 1). The occluder device did not engage the posterior side but instead passed between the right upper and lower pulmonary veins (PV), obstructing the right upper PV (velocity of 110 cm/s).

![Figure 1. The echocardiogram of patient 1, revealing secundum ASD and displacement of the ASO (yellow asterisk).](image1)

![Figure 2. The closure process of a secundum ASD in patient 1 using a peri-cardial patch.](image2)
and increasing the risks of pulmonary hypertension (PH). Right heart catheterization (RHC) showed a detached occluder device in the large secundum ASD, obstruction of the right upper PV, and mild PH. The aortic pressure was measured at 85/62 (72) mmHg, and the pulmonary artery pressure was 42/17 (29) mmHg.

Due to the patient’s stable condition, surgery was performed to remove the detached device. During the surgery, secundum ASD with a diameter measuring 3x2 cm was discovered. An occluder was found on the superior rim of the ASD, which had become detached and migrated towards the right lower pulmonary vein (PV), positioned above the mitral valve. The posterior occluder leaflet was removed by replacing part of the rim, and the device was detached from the clutch, with part of the rim being cut. The evacuated occluder device appeared intact. The remaining secundum ASD was then closed with an autologous pericardial patch (Figure 2). Intraoperative data showed that cross clamp time was 23 minutes with coronary pulmonary bypass time was 46 minutes. After the surgery, an echocardiography evaluation showed that the ASD had been successfully closed with no residual remnant. During the postoperative evaluation, the patient no longer complained of shortness of breath, while the laboratory results were within normal limits. The patient was discharged on the seventh day of treatment.

**Cases 2**

In another case, a 12-year-old boy presented without any complaints and was referred from a secondary hospital with an echocardiogram that showed the displacement of the occluder device into the right ventricle. The patient had a history of a secundum atrial septal defect (ASD), but he had been asymptomatic until a cardiac murmur was noticed at routine visit to a pediatrician. An echocardiography was performed on the patient, which revealed mild tricuspid regurgitation (TR) along with the secundum ASD. The patient was then scheduled for ASD closure with an atrial septal occluder device via catheterization at the secondary hospital. The patient had no complaints during the 1-month follow-up after the occluder placement. However, during the 2-month follow-up, it was discovered that the occluder had been misplaced into the right ventricle, prompting the referral to our tertiary hospital.

Upon arrival at our tertiary hospital, the patient was in good health and had no complaints. He weighed 34.7 kg and was 147 cm tall. Vital signs indicated a blood pressure of 120/74 mmHg, a heart rate of 81 beats per minute, a respiratory rate of 21 breaths per minute, and oxygen saturation of 97% in room air. Cardiac examination revealed a normal S1 heart sound, while the S2 heart sound had an intermittent split, and a grade 3/6 pansystolic murmur was heard in the intercostal space (ICS) IV-V. Chest X-ray showed an occluded appearance in the left paravertebral
projection at the level of thoracic vertebrae VII-IX, as well as enlargement of the left atrium and right ventricle. Further echocardiography examination was performed to confirm that the occluder device had become displaced and was now situated in the right ventricle. There was also evidence of a secundum ASD with a left-to-right shunt and mild TR with a peak pressure gradient of 21.5 mmHg (Figure 3). Right heart catheterization was not performed.

Because the patient was stable; therefore, surgery was performed to retrieve the displaced device. During the procedure, a secundum ASD with a diameter measuring 2x1cm was discovered. The occluder was found behind the anterior cusp of the tricuspid valve (Figure 4). The retrieved occluder device appeared intact, and there was found to be an injury to the tricuspid valve, but fortunately no rupture was detected. The remaining secundum ASD was then closed with an autologous pericardial patch (Figure 5). Intraoperative data indicated an aortic cross-clamp duration was 20 minutes, and the coronary pulmonary bypass time was 38 minutes. After the operation, an echocardiography evaluation showed that the ASD had been successfully closed with no residual remnant. During the postoperative evaluation, the patient had no complaints, and he was discharged on the 6th day of hospitalization.

The comparison of patient cases are presented in the following Table 1.

**DISCUSSION**

ASD is caused by an atrial septum malformation, which results in blood shunting from the systemic to the pulmonary circulation. As a result, the majority of ASD patients remain asymptomatic and undiagnosed until adulthood. With advancing age and without proper management, patients may experience exercise intolerance, arrhythmias, right ventricular dysfunction, pulmonary hypertension, and an increased risk of mortality. The incidence of mortality and pulmonary complications is higher in women and older patients. Furthermore, there is a potential for the blood flow to change from the right atrium to the left atrium, known

<table>
<thead>
<tr>
<th>Name</th>
<th>Case 1</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>9 years old</td>
<td>12 years old</td>
</tr>
<tr>
<td>Gender</td>
<td>female</td>
<td>male</td>
</tr>
<tr>
<td>Primary Disease</td>
<td>ASD</td>
<td>ASD</td>
</tr>
<tr>
<td>Timing of events</td>
<td>3 years</td>
<td>2 months</td>
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<tr>
<td>Cardiac physical examination</td>
<td>normal limits</td>
<td>normal limits</td>
</tr>
<tr>
<td>Preoperative echocardiography</td>
<td>secundum ASD, L to R, mild PH</td>
<td>secundum ASD, TR mild</td>
</tr>
<tr>
<td>Defect size (diameter, mm)</td>
<td>3x2cm</td>
<td>2x1cm</td>
</tr>
<tr>
<td>Device migration site</td>
<td>left atrial</td>
<td>right ventricle</td>
</tr>
<tr>
<td>Surgical management</td>
<td>ASO removal and ASD repair with pericardial patch</td>
<td>ASO removal and ASD repair with pericardial patch</td>
</tr>
<tr>
<td>Aox time (min)</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>CPB time (min)</td>
<td>46</td>
<td>38</td>
</tr>
<tr>
<td>Hospital LOS (days)</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>

as Eisenmenger syndrome. This condition can cause cyanosis, dyspnea during activities, increased pulmonary vascular resistance and infections, and a potential for transient ischemic attacks or strokes. The majority of ASDs with small defects, less than 5mm, will close spontaneously within the first year of life. Larger defects, exceeding 1cm in size, pose greater challenges for closure and may demand additional interventions. According to the practical guidelines of the American Heart Association (AHA), indications for ASD closure include secundum ASD with hemodynamic disturbance, a ratio of pulmonary cardiac output (CO) (QP) to systemic CO (QS) exceeding 1.5:1, the occurrence of stroke or transient ischemic attack, and the presence of systemic cyanosis due to transient right-to-left shunt.\(^{11,12}\)

Surgical closure of ASD has long been the standard of treatment, and in 1976, the first attempt of ASD closure was first carried out using percutaneous transcatheter devices. This approach has become routine, particularly in pediatric cases. Transcatheter ASD closure is associated with fewer post-procedural complications compared to surgical closure, including a shorter hospital stay, lower rates of morbidity and mortality, avoidance of surgical risk factors, and absence of surgical scars.\(^{10-12}\) Transcatheter closure is preferred for hemodynamically significant secundum-type ASDs with a Qp/Qs ratio exceeding 1.5:1, as well as in patients at risk of thromboembolic events. However, for larger defects or those lacking sufficient rims for septal occluders, transcatheter closure may not be the optimal management. In cases of cryptogenic embolic stroke with a patent foramen ovale (PFO) or right-to-left ASD shunt, transcatheter PFO closure proves more effective in reducing recurrent ischemic stroke compared to medical antithrombotic agents, despite the associated device-related complications and increased risk of atrial arrhythmias.\(^{12,13}\) Additionally, there are contraindications for transcatheter closure of ASD, such as small hemodynamically stable ASDs, ASDs with types other than secundum septal defects, or secundum defects with pulmonary hypertension. The success rate of device implantation in ASDs is 98%, with the majority of patient experiencing complete closure within two years.\(^{13}\) While extremely rare, early and late complications of percutaneous ASD closure include device embolization, cardiac erosions, arrhythmias, and thromboembolism leading to transient ischemic attacks or strokes, pericardial effusion, valve damage/regurgitation, and conduction abnormalities.\(^{5,13}\)

In both of our cases, the patients were still in their childhood when diagnosed with ASD. Both patients had secundum ASD, where the defect occurs in the fossa ovalis due to one or several defects in the septum primum, while the septum secundum is well-formed, as seen in both of our patients. Surgical closure is highly anticipated to be performed before the age of 25 to maximize life expectancy potential. On the other hand, catheter-based closure can be performed on secundum ASD that meets the criteria for appropriate anatomy and size.\(^{2}\) Percutaneous closure of the defect was conducted. The size of the defect can range from a few millimeters to 3 cm, and in our cases, the secundum ASD defect was not more than 0.5 cm. The size of the ASD defect affects the outcome of blood shunting flow; most ASD patients experience left-to-right shunting, especially in late systolic and early diastolic phases. Additionally, atrial pressure and the compliance of both ventricles are factors influencing the direction of shunting.\(^{14}\) When closing the ASD with ASO, both patients had a Qp:Qs ratio >1.5:1, indicating an increase in this value leading to volume overload and pressure overload on the right ventricle. This can reduce left ventricle compliance, result in remodeling of the pulmonary vascular bed, which lead to pulmonary hypertension.\(^{14}\)

ASO are inserted through a catheter from the femoral vein, guided by echocardiography and/or fluoroscopy, to position them on the atrial septum. Once in place, the occluder expands and is pushed with the catheter to seal and close the defect. It is anticipated that after placement, reendothelialization will occur on the rim and the surrounding area of the device, strengthening and securing its position. However, device migration may occur if this process fails, leading to unstable devices, especially due to a rim deficiency in the ASD or a mismatch in sizes between the ASD and the device.\(^{15,16}\) Reported from the Manufacturer and User Facility Device Experience (MAUDE) database, the incidence of ASO devices migration was between 0.5% and 2% worldwide. This number has decreased in the last 20 years, especially with the use of new generation devices since 2005. The majority of these devices have been successfully removed, either through transcatheter procedures or open-heart surgery.\(^{17-19}\) In most cases, device embolization typically occurs within 24 hours post-implantation. Although rare, instances of migration may incidentally be discovered during follow-up echocardiograms several months after device placement. Morbidity resulting from ASO migration is very uncommon and easily manageable without complications. However, some studies report cases where patients have succumbed to stroke or cardiac perforation.\(^{16-20}\) Several factors that increase the risk of embolization include inadequate operator (learning curve) experience, inaccurate deployment due to a larger defect size with floppy or deficient rims to hold the devices, thin atrial septal tissue that leads to tearing, mostly in the lower rim, the use of an undersized device, and alterations in the device’s position after deployment. The likelihood of embolization may be heightened by excessive tension on the delivery cable or excessive maneuvering.\(^{21-23}\)

The assessment of ASD using TEE requires an evaluation of the number and localization of the defect, dimensions, and adequacy of the rims, defined by the presence of a minimal 5mm of rims. There are several rims in ASD, including the aortic rim, superior vena cava (SVC) rim, superior rim, posterior rim, inferior vena cava (IVC) rim, and atroventricular (AV) valve rim.\(^{24}\) The majority of ASD defects typically involve a deficiency in the aortic rim, followed by the inferior vena cava margins. The absence of an aortic rim is a significant predictor of both tissue erosion and the occurrence of early and late embolization.\(^{23,24}\) The lack of both rims increases the susceptibility of embolization and displacement.\(^{25}\) The migration of the ASO may lead to mispositioning at...
various locations, with the most common occurrence in the right ventricle and pulmonary artery. However, it can also embolize to the left atrium or ventricles, and in rare cases, it may follow the flow through the ascending aorta or abdominal aorta. Most of these cases require surgical intervention. DE can exhibit symptoms depending on their location.\textsuperscript{26} For instance, an occluder lodged in the right ventricle may be asymptomatic if it does not disturb pulmonary circulation; however, disruption of pulmonary blood flow can lead to volume overload on the right ventricle, causing right heart failure or arrhythmias.\textsuperscript{25,27} The symptoms will be influenced by the degree of pulmonary obstruction. On the other hand, left-sided dislodgement is mostly symptomatic due to the potential obstruction of left ventricular flow, leading to dyspnea and symptoms of left heart failure.\textsuperscript{24,28,29} Therefore, embolized devices disrupting hemodynamics and causing obstruction need to be removed.

The removal of ASO can be accomplished through either surgical procedures or percutaneous retrieval. Surgical removal is prioritized for chronic dislodgements, especially when discovered several years after implantation or in cases involving right heart failure. Nevertheless, attempts at percutaneous removal may be considered as a primary strategy for embolization in large vessels, although the approach carries a higher risk when used for evacuating devices in cardiac chambers, as it is prone to causing valve injuries.\textsuperscript{30}

In one of our cases, the ASO was located in the left atrium, while in the other case, it was entangled in the right ventricle, behind the tricuspid valve. The left-side migration caused dyspnea in the first patient, whereas, due to the lack of obstruction and good right ventricular compliance, the second patient remained asymptomatic. We opted not to perform catheter-based removal of the ASO due to chronic embolization of the devices. After the removal of the devices, the remnant of the defect was closed with a pericardial patch. Fortunately, in the postoperative period, we did not encounter any embolism, tamponade, or arrhythmias.

To preventing the device embolization, echocardiography examination is essential for evaluating the anatomy of the rims and assessing the defect size. This assessment should be performed in at least three TEE views, including the four-chamber view for the AV valve and superior rim, aortic short-axis view for the aortic and posterior rim, and bi-caval view for SVC and IVC rim.\textsuperscript{30} Considering that the majority of dislodgement incidents are likely to occur in the initial hours after implantation, continuing through the first and second days, and are rarely reported in weeks, months, or a few years after placement, it is crucial to maintain vigilant monitoring of the patient. After discharge, follow-up echocardiographs at two weeks and three months are necessary, followed by a six-month follow-up to prevent late complications.\textsuperscript{26,30} The selection of the occluder size is essential, as undersized devices may tend to detach, especially in cases of large ASD defects or defects in a wide aortic rim. On the other hand, oversized ASOs can lead to tissue erosion around the rim area. Additionally, surgical closure of ASD using a pericardial patch can be an alternative, especially for large ASD defects.\textsuperscript{31-33}

**CONCLUSION**

The occurrence of ASO migration is uncommon, necessitating further surgery for device removal, closure of the remaining defect, and ensuring the absence of cardiac erosion or rupture. Additionally, surgery for retrieving the devices has a minimal risk of morbidity and can alleviate symptoms such as shortness of breath and palpitations.

**ETHICS APPROVAL AND CONSENT TO PARTICIPATE**

Patient legal guardian had received signed written informed consent regarding publication of medical data in scientific medical journal, with confidentiality aspect towards personal information. This report has been approved by Ethical Committee of Medical and Health Research Ethics Committee (MHREC) Faculty of Medicine, Public Health and nursing, Universitas Gadjah Mada – Dr. Sardjito General Hospital, Indonesia with ethical clearance reference number KE/ FK/1852/EC/2023.

**DATA AVAILABILITY STATEMENTS**

The data underlying this article will be shared upon reasonable request with the corresponding author.

**CONFLICT OF INTEREST**

The authors declare that there is no conflict of interest.

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**AUTHORS CONTRIBUTION**

Conceptualization, methodology, formal analysis, data curation, visualization, writing-original draft, writing-review and editing, project administration, supervision: Yuletta Adny Ambarsari Conceptualization, validation, supervision, writing-original draft, writing-review, and editing: Supomo, Haryo Aribowo, Yunanto Kurnia, Ilhsanul Amal, Irawan Satriotomo, Methodology, formal analysis, data curation, visualization, writing-original draft, writing-review, and editing: Tandeem Tommy Novenanto

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**REFERENCES**

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