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# Arrhythmias and conduction disorders associated with atrial septal defects

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**Abstract:** Atrial septal defects (ASDs) are the most common form of congenital heart disease. There are 4 embryologic types of ASDs, and rhythm considerations vary based on type. ASDs have left-to-right shunt and primarily right-sided volume overload. This leads to electrical remodeling that may predispose patients to atrial tachyarrhythmias and conduction disorders. Risk for arrhythmias is increased with late age of ASD repair, shunt size, other factors such as pulmonary hypertension and comorbid conditions. Arrhythmia incidence is decreased after ASD closure, but remains elevated compared to general population. Medical and procedural therapy for arrhythmias should consider type and timing of ASD repair. Conduction disorders are rare. Sinus node dysfunction may be seen with late age of repair and large shunt size. Sinus venosus ASD exhibits a higher rate of sinus node dysfunction, especially with older surgical techniques. Ostium primum ASD has higher risk of spontaneous or post-operative AV block, though this is rare with current surgical techniques. Risk of AV block with surgical repair or device closure of secundum ASD is rare. Familial ASDs and other forms of congenital heart disease may be seen with mutations in associated myocardial transcription factors NKX2.5, GATA4, TBX6, along with conduction disorders such as AV block.

**Keywords:** Electrophysiology; atrial septal defect (ASD); arrhythmia; conduction

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## Background

Atrial septal defects (ASDs) are the most common form of congenital heart disease, and account for approximately 6–10% of congenital heart defects, with approximate population incidence of 1–3 per 1,000 (1). There are multiple types of ASDs, including ostium secundum defects, ostium primum defects, sinus venosus defects (inferior and superior), and coronary sinus defects (1,2). While a detailed discussion is beyond the scope of this article, a knowledge of the fundamental anatomic and embryologic characteristics of each type of ASD is crucial to understanding and anticipating the types of arrhythmias and conduction disorders that may arise. All ASDs typically

result in a left-to-right shunt, resulting in right atrial enlargement, right ventricular dilation and, to a lesser extent, left atrial enlargement, generally all correlated to the Qp:Qs of the shunt. Shunt size alone has been correlated with arrhythmias, beyond other associations or risk factors (3).

Ostium secundum defects are the most common type of ASD, accounting for an estimated 75% of ASDs. Ostium secundum defects occur at the location of the fossa ovalis, and are thought to result from insufficient growth of the septum secundum or excessive regression of the septum primum, resulting in a septal defect (1,2). Size may range from very small, similar in physiology and appearance to a patent foramen ovale, to very large. Shunt

size is typically correlated with defect size and diastolic relaxation. In this location, the defect itself is generally remote from the specialized conduction structures, though these may still be impacted by repair or closure techniques. Electrocardiograms (ECGs) in ostium secundum defects may exhibit right axis deviation and right ventricular conduction delay or right ventricular hypertrophy (2,4).

Ostium primum defects represent approximately 15% of ASDs. They fall in the spectrum of partial endocardial cushion abnormalities, or partial atrioventricular septal defects. They occur in the anterior portion of the lower atrial septum, and are often associated with a mitral cleft or other atrioventricular valve abnormalities. Primum ASDs are often large in size, and mitral regurgitation may add to hemodynamic impact (2). The vast majority of ostium primum defects exhibit left axis deviation on electrocardiograms, thought secondary to congenitally anomalous atrioventricular conduction similar to the inferoposterior displacement of the AV node and His bundle in complete AV septal defects, or potentially left ventricular volume overload from mitral regurgitation (4,5). Ostium primum defects and other endocardial cushion abnormalities may be associated with trisomy 21, DiGeorge syndrome, and Ellis-Van Creveld syndrome (2).

Sinus venosus defects include both superior and inferior defects and account for approximately 5–10% of ASDs. Superior sinus venosus defects occupy the posterior and superior portion of the atrial septum, often overriding the superior vena cava. Inferior defects occupy the posterior and inferior septum, near to or overriding the inferior caval orifice. Anomalous pulmonary venous drainage is common in these defects, with anomalous drainage to the superior vena cava particularly common in superior sinus venosus ASDs. The close proximity of the crista terminalis and sinus node to superior sinus venosus ASDs has implications in the development of sinus node dysfunction, both pre-operatively and post-operatively from repair (2,6,7).

Coronary sinus defects are rare in comparison to other forms of ASDs. Rhythm considerations beyond the effect of left-to-right shunting have not been widely reported.

### General electrophysiologic principles

The chronic left-to-right shunt associated with ASDs leads to increased hemodynamic load and geometric remodeling, both at a cellular and macroscopic level. This is most commonly seen in the right atrium and right ventricle, but

has also been described in left heart structures, particularly if there are associated mitral valve concerns as commonly seen with primum ASDs (2,3). This chronic volume stress leads, in turn, to electrical remodeling that may precipitate development of arrhythmias. Atrial myocyte electrophysiologic properties are altered, with increased intra-atrial conduction time a common finding, likely from combination of interstitial fibrosis and chamber enlargement (4,8). Sinus node conduction properties may also be as altered, even in the pre-operative state (8,9). While chamber size may improve following ASD closure or repair, many of the electrophysiologic characteristics appear to have no, or minimal, improvement (2,8,9). Different types of ASDs may also have specific impact on the sinus node and/or AV node depending on embryologic origin and anatomic proximity as noted prior.

### Tachyarrhythmias

Atrial tachyarrhythmias are commonly seen in patients with ASDs, regardless of ASD type. Atrial flutter and atrial fibrillation are relatively rare in childhood, but become more prevalent with increasing age at time of repair or closure (2,3,10-12). Atrial arrhythmia prevalence is also correlated with size of shunt and hemodynamic complications such as pulmonary hypertension, as well as with other comorbidities (3,11,12). Atrial flutter and atrial fibrillation in patients with ASDs may be treated in similar fashion to the general population, with appropriate consideration for rhythm control strategies with anti-arrhythmic medications and electrical cardioversion as indicated (3). Appropriate anti-coagulation guidelines should also be followed (13). Consideration should be made for ASD closure or repair as part of reducing risk of tachyarrhythmia recurrence and improving symptoms (2,3,11,14).

Other forms of SVT are also commonly seen in patients with ASDs, including atrioventricular reciprocating tachycardia (AVRT) and atrioventricular node reentrant tachycardia (AVNRT), as well as rarer automatic tachyarrhythmias such as atrial ectopic tachycardia (3,11). While there is little data on best clinical management of these arrhythmias specifically in patients with ASDs, common practice supports typical medical management of these arrhythmias. If transcatheter ablation is considered as a therapeutic modality, additional timing strategies are prudent (3,11). First, in patients with identified SVT, electrophysiology study and ablation should be considered prior to device closure or surgical repair of the ASD

in order to avoid a potentially complicated transseptal puncture in the case of a left-sided SVT substrate (e.g., left atrial focus of AET or left-sided accessory pathway) (3,15). An appropriate monitoring period is prudent post-ablation to ensure no clinical recurrence of SVT prior to closing ASD. Second, in patients with AVNRT and a large secundum ASD, device or surgical closure may have impact on the AV nodal fast pathway. In cases such as this, slow pathway modification may entail higher risk of incurring AV nodal conduction abnormalities. Thus, in patients with clearly defined AVNRT, consideration for postponing ablation until after recovery from ASD closure may be prudent. In patients with primum ASDs, there should be careful consideration and assessment of anatomic differences in AV node and other conduction tissues prior to any attempt at ablation.

Following closure of ASD, other considerations arise for evaluation and treatment of tachyarrhythmias. Incidence of atrial tachyarrhythmias is decreased post-closure, but recurrence rate may still be significant, particularly in patients who underwent ASD closure at older age, had larger shunts, or with other comorbidities (3,8,11,16,17). After surgical closure, additional macro-reentrant intra-atrial circuits may exist, most commonly around the atriotomy site and borders of ASD patch. Typical cavotricuspid isthmus-dependent atrial flutter may also occur, sometimes in a complex double loop (figure 8) with other intra-atrial reentry circuits. These are often amenable to transcatheter ablation techniques (3,11,14,17). Automatic atrial tachycardia foci may also occur at sites of scarring or suture lines. There are rare reports of new-onset atrial tachycardia post-device closure, potentially secondary to mechanical effect of the device itself (18).

In patients with persistent atrial fibrillation post-closure, or with a left-sided SVT substrate, transseptal puncture may be complicated by the ASD patch or device. Various techniques have been described as successful, including use of RF transseptal wire/needle and standard needle puncture through the ASD device itself (15,19,20). Transesophageal or intracardiac echo can be helpful in determining optimal puncture site and needle position in relation to other structures (19,20).

### Conduction disorders

Both sinus node and AV nodal conduction abnormalities have been reported in patients with ASDs. Electrophysiologic markers of sinus node dysfunction have been described

in many patients with ASDs (9,21). Clinical sinus node dysfunction has been reported both pre- and post-procedurally for ostium secundum ASDs and ostium primum ASDs (9). Risk of developing sinus node dysfunction is correlated with larger shunt size and older age at closure (2,3,22).

In patients with superior sinus venosus ASDs, the proximity of the septal defect to the crista terminalis and sinus node presents a higher risk of developing sinus node dysfunction. This has been reported pre-operatively in some patients, but more commonly has been reported as a complication of surgical intervention, with rates of sinus node dysfunction as high as 10–15%. More recent surgical techniques such as the Warden procedure or modified double patch technique demonstrate a much lower incidence of sinus node dysfunction, around 1–2%. These techniques avoid an incision across the cavoatrial junction, likely reducing the risk of direct trauma to the sinus node and also preventing injury to the sinoatrial artery (6,7).

First degree AV block is seen in many patients with ASDs, largely secondary to prolonged intra-atrial conduction time (5,8). Higher-grade AV nodal conduction abnormalities are most frequently seen in patients with ostium primum ASDs. This is likely secondary to the displacement of the AV node and His bundle and the proximity of the defect to these structures (5). AV block in these patients may develop spontaneously over time with no surgical or procedural intervention (21,23). Post-surgical AV block may also develop from injury to the conduction system during patch repair, though this is rare with modern surgical techniques (2,24).

Pre-procedural AV nodal conduction disorders are rare with other ASD types. Device closure and surgical repair of ostium secundum ASDs both have rare incidence of high-grade AV block following the procedure. Incidence of high-grade persistent AV block for both techniques is at or below 1% in multiple retrospective studies (22). High-grade AV block from device closure typically occurs in the first 24-hour post-procedure and resolution rate is high if device is removed. Risk factors include young age and large defect/device size (23).

AV block may also be found in patients with ASDs secondary to mutations in a family of closely-associated myocardial transcription factors that are active in early embryologic development, NKX2.5, GATA4 and TBX5). TBX5 is associated with Holt-Oram syndrome, which also has extra-cardiac manifestations of upper extremity

abnormalities such as absent radial bone or polydactyly. Mutations in these transcription factors exhibit autosomal dominant inheritance and are associated with multiple forms of congenital heart disease, most commonly with secundum ASDs. AV block may be gradually progressive or sudden in onset. Sinus node dysfunction has also been reported with these mutations, though less commonly (25,26). Testing for these mutations should be considered if there is a family history of ASDs, other forms of congenital heart disease, or AV block, or if the individual patient exhibits a constellation of symptoms or findings consistent with a mutation in one of these genes (25,26).

### Summary

Arrhythmias and conduction disorders are well-described in patients with ASDs. Atrial tachyarrhythmias such as atrial flutter and atrial fibrillation are rare in childhood, but become increasingly common with older age at time of repair, larger shunt size and comorbidities. Other forms of SVT may also occur. Medical treatment of arrhythmias in patients with ASDs is similar to treatment strategies in the general population. Procedural treatments such as ablation should be undertaken in consideration of timing and type of ASD closure. Incidence of arrhythmias decreases after closure of ASD, but remains elevated in comparison to general population, particularly with late age of repair. Conduction disorders are rare with ASDs generally: sinus node dysfunction is associated with sinus venosus ASDs and repair; AV block is associated with ostium primum ASDs. Both sinus node dysfunction and AV block are rare with modern surgical techniques and with device closure. Mutations in myocardial transcription factors NKX2.6, GATA5 and TBX5 are associated with familial ASDs, other forms of congenital heart disease and conduction disorders, especially AV block. Knowledge of embryologic origin of both the conduction system and different types of ASDs helps to guide anticipation of rhythm concerns, clinical evaluation and counseling.

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### Footnote

*Conflicts of Interest:* The authors have no conflicts of interest to declare.

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