Atrial septal stenting — How I do it?

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ABSTRACT

A wide atrial communication is important to maintain hemodynamics in certain forms of congenital and acquired heart defects. In comparison to balloon septostomy or blade septostomy, atrial septal stenting provides a controlled, predictable, and long-lasting atrial communication. It often needs a prior Brockenbrough needle septal puncture to obtain a stable stent position. A stent deployed across a previously dilated and stretched oval foramen or tunnel form of oval foramen carries higher risk of embolization. This review provides technical tips to achieve a safe atrial septal stenting. Even though this is a "How to do it article," an initial discussion about the indications for atrial septal stenting is vital as the resultant size of the atrial septal communication should be tailored for each indication.

Keywords: Atrial septal stent, butterfly stent, dog-bone stent, stent embolization, trans-septal puncture

INTRODUCTION

An adequate interatrial communication is crucial to maintain the hemodynamics in certain forms of congenital and acquired heart defects. Inadequate atrial communication may affect the hemodynamics by:

1. Leading to pulmonary venous hypertension,
2. Contributing to low systemic cardiac output, and
3: Providing inadequate inter-circulatory mixing in different forms of congenital cardiac defects.[1]

Atrial septal stenting was advocated as one method among the various surgical and transcatheter techniques of providing a reliable and predictable interatrial communication.[2] This review discusses the indications and procedural details of atrial septal stenting. The different procedural risks of atrial septal stenting in various ages and anatomy should also influence the cardiologist to choose the most appropriate alternative option listed in Table 1.

Indications for atrial septal stenting

The hemodynamic benefits of an atrial septal defect may vary in different situations.

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(1) Relief of left atrial hypertension

Intact atrial septum or very restrictive oval foramen in patients with hypoplastic left heart syndrome, leads to severe pulmonary venous hypertension, supra-systemic pulmonary vascular resistance, and severe hypoxia.[3] The resultant pulmonary lymphangiectasia leads to irreversible lung changes and may even contraindicate a neonatal heart transplant.

(2) Maintenance of systemic cardiac output

Adequate atrial septal defect is important to maintain systemic blood flow in:

1. Tricuspid atresia and total anomalous pulmonary venous drainage,
2. Right ventricular outflow obstructions where right ventricular output is critically reduced, and
3. Severe pulmonary arterial hypertension with failing right ventricle.[4,5]

(3) Inter-circulatory mixing

In transposition physiology, unfavorable streaming of systemic venous blood into the aorta can be reduced by creation of a large interatrial communication which improves the effective systemic and pulmonary blood flows.[6,7]

(4) Reducing pulmonary vascular resistance in biventricular circulation

If post tricuspid shunts coexist with mitral stenosis, reflex pulmonary arteriolar spasm due to pulmonary venous hypertension will reverse the shunt and lead to aortic desaturation. In such patients, atrial communications will improve their operability by reducing the pulmonary vascular resistance.

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Table 1: Methods of creation of atrial septal defect

Transcatheter options		
Balloon atrial septostomy	Tear oval fossa	Balloon catheter from femoral or umbilical vein
Z-5 balloon septostomy	Over the wire balloon	Allows repeated passages of balloon
Static balloon dilatation	Stretches an atrial septal defect/patent oval foramen	Pre-existent defect is needed
Brockenbrough septoplasty	Trans-septal puncture followed by balloon	When there is no preexistent atrial septal defect
Blade atrial septostomy	Blade cuts the limb of oval fossa	5-15 mm blade is directed away from the anterior aortic root
Atrial septal stenting	Stent across the atrial septal defect	Stent prevents recoil of the atrial communication
Surgical options		
Atrial septectomy	Midline sternotomy on cardiopulmonary bypass	Most reliable method
Septectomy on beating heart	Inflow occlusion, right atriotomy and septectomy	Transient clamping of caval veins
Thoracoscopic scissors	Right atrial purse string, stab thoracoscopic scissors	Atrial septal cut on trans esophageal echo guidance
Without CPB	Fibrillatory arrest, right atriotomy and septectomy	Induce cardiac arrest by ventricular fibrillator
Blalock Hanlon septectomy	Thoracotomy without cardiopulmonary bypass	Excision around Sondergaard groove
Hybrid procedure	Purse string on right atrial wall	Guidewires, balloons and blades used through this entry

(5) Reducing pulmonary vascular resistance in univentricular heart
Reducing the left atrial pressure is an important prior step to facilitate palliative Glenn and Fontan surgeries in single ventricle with mitral stenosis.[8]

(6) In patients on extracorporeal membrane oxygenation support for severe left ventricular systolic dysfunction and secondary mitral regurgitation, high left atrial pressures may lead to persistent lung edema and hemorrhage. Atrial septal stenting will decompress the left atrium effectively.[9]

Vascular access

The procedure is commonly done from right femoral vein, which allows a straight passage to the oval fossa. Left femoral venous access gives a sharp angulation between the left iliac vein and inferior caval vein and poses difficulty for trans-septal puncture. Umbilical venous access is almost never used for two reasons. Umbilical vein obliterates due to fibrosis after the first few days after birth making it unavailable. The tortuosity from the umbilicus to atrial septum through the venous duct and left hepatic veins poses difficulty for stenting. Transhepatic access is an alternative if femoral veins are occluded or inferior caval vein is interrupted.[10] If no vascular access are available, hybrid surgical access through a double-layered hemostatic purse string suture around the right atrial wall after limited thoracotomy or sternotomy may be required. Atrial septal interventions need an access that will be perpendicular to the plane of the atrial septum. Since jugular venous access never achieves a perpendicular access to the atrial septum, it is seldom used.

Morphology of atrial septum

In patients with hypoplastic left heart syndrome, the left atrium is small, oval fossa is not well-formed and the atrial septum is often thick and muscular.[11] Echocardiographic scoring systems can serve as a guide regarding the rigidity of the atrial septum.[12] In these patients, an interatrial septal puncture with a Brockenbrough needle through the femoral vein or perforation with a radiofrequency guidewire (Baylis Medical, Montreal, QC, Canada) or a specially designed sharp trans-septal perforation wire (Safesept Pressure products, San Pedro, CA, USA) is needed before stenting.[13] The atrial septum is similarly thick and muscular in older patients with severe congenital mitral stenosis associated with univentricular heart or post tricuspid shunts. In some patients, a long tunnel-like communication may exist in the oval foramen. A septostomy balloon or a static dilatation can stretch these communications very well, but the high left atrial pressures will push the primum septum against the limb of oval fossa and close it again.[2] This makes balloon septostomy and static balloon septoplasty very ineffective in these situations. If a stent is deployed in these tunnels, it very often embolizes to right atrium. It is important not to stent through the tunnels in the oval fossa, as the stent will never be gripped well in these tunnels.[13]

Initial steps

Detailed hemodynamic pressure data recording is very vital to guide further steps in patient management. An arterial line helps to monitor the periprocedural aortic pressures, document the severity of hypoxia, and acidosis, enable correction of the electrolyte imbalance and guide ventilator settings. In patients with very small left atrium, angiogram is done in the right pulmonary artery to delineate the contours of the left atrium on the levo-phase. If biplane fluoroscopy is available, this levo-phase is recorded on lateral view too [Figure 1]. This contrast injection is avoided in patients with pulmonary edema, renal failure, severe metabolic acidosis, or compromised hemodynamics.

Septal puncture

A 0.032” J tipped guidewire is parked in the left innominate vein through the right superior caval vein and a transseptal sheath is advanced over it. Left innominate vein may be absent if there is a persistent left superior caval vein entering the right atrium through a dilated coronary sinus. In such instances, the sheath tip is parked in the right jugular vein. A 0.021" tipped pediatric Brockenbrough septal puncture needle is introduced under fluoroscopic guidance till its tip reaches the end of the transseptal sheath. The arrow of the flange of the needle should point posterior and to the left at 4–5 o' clock position. The transseptal sheath-needle assembly is withdrawn down towards the right atrium till the tip of the sheath passes the limb of oval fossa, as recognized by appearance of atrial ectopics. During septal puncture in adults before balloon mitral valvotomy, the tip of transseptal catheter is pointed posterior to a pigtail catheter in aortic root. However, most clinical situations like hypoplastic left heart syndrome and univentricular hearts with malposed aorta will preclude any catheter positioning in the aortic root. So placing a catheter in aortic root to guide the needle tip is not mandatory for septal puncture. Staining the atrial septum is often done with small injections of contrast to guide the site of puncture.

Echocardiographic guidance for septal puncture

It is useful to guide the septal puncture site with transthoracic or transesophageal echocardiography. In small neonates, recent micro transesophageal echocardiographic probes may facilitate intraprocedural guidance.[14] Intracardiac echocardiographic probes (Acunav 8F catheters, Siemens) can be passed through the esophagus and may be an alternative to the micro transesophageal echocardiographic probe in very small neonates, even though the view is limited to single bicaval longitudinal plane only. The intracardiac echocardiographic probes don't have a thermistor and so are liable to get heated up if used for prolonged periods. In hybrid procedures, direct epicardial echocardiography may also be used to guide the site of puncture.

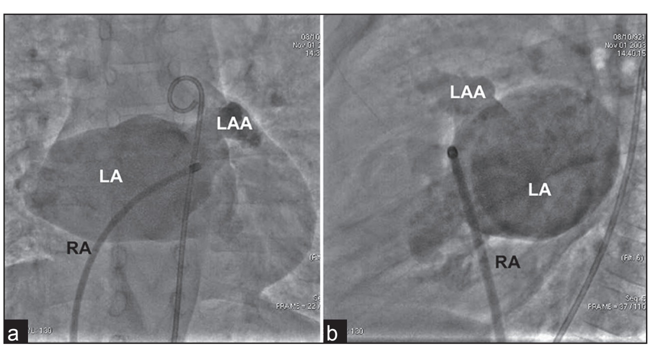

Figure 1: Left atrial (LA) contours are delineated on the levophase of pulmonary artery angiogram or right ventricular outflow angiogram in both anteroposterior view (a) and lateral view (b) on biplane fluoroscopy. RA-right atrium, LAA-left atrial appendage

After the septal puncture

Once a contrast injection through the transseptal needle confirms left atrial entry, the transseptal sheath is advanced into the left atrium. Heparinisation is done after confirming septal puncture. Since the size of left atrium is very small in hypoplastic left heart syndrome, a 0.014" coronary guidewire with floppy tip is advanced into the left atrium immediately after the needle tip enters the left atrium [Figure 2]. When the needle and septal sheath are advanced over this guidewire, an inadvertent injury to the roof of the left atrium and appendage is avoided. Once the stability of the position of the transseptal sheath is confirmed, the needle is exchanged with a 0.018" stiff torque guidewire like Platinum plus (Boston scientific Co) or Road-runner (Cook Medical) wire. In some situations, a 0.035" stiff torque wire like Magic torque (Boston scientific) wire is used.

Choice of stents

Pre-mounted stents are always preferred to avoid stent embolization. These stents are firmly mounted on low profile balloons in a very secure manner. Examples of such stents are Genesis (Cordis Inc), Valeo (Bard vascular), Formula (Cook medical), Visipro (ev3 medical), and are usually compatible through 6-7 F sheaths. Bare stents need mounting on larger profile balloons and carry chances of stent slippage. The stent is advanced completely covered within the transseptal sheath, when stent crosses the atrial septal plane. Since the atrial septum is often pliable, very high radial stress is not a necessary attribute for a stent to be deployed in atrial septum.

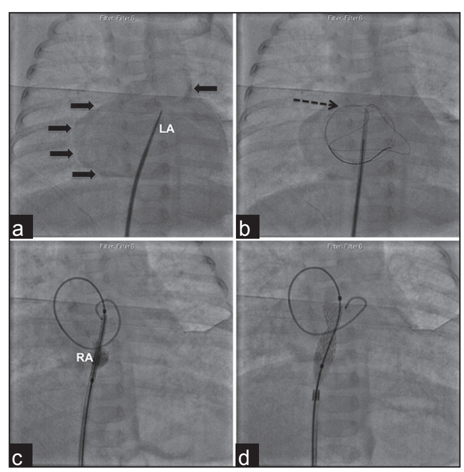

Figure 2: Atrial septal stenting in univentricular heart with mitral stenosis. During septal puncture (a), the needle tip pierces the left atrial (LA) roof and contrast stains the pericardial cavity shown by multiple arrows. The needle is withdrawn minimally (b) and a coronary floppy guidewire (dotted arrows) is advanced to coil in the left atrium. After exchanging to a stiff guidewire, a stent is partially unsheathed across the atrial septum (c) with check injections from the sheath tip into the right atrium (RA). Finally, stent is deployed (d) with a dog-bone configuration

Role of echocardiography

Prior echocardiographic evaluation before stenting of the atrial septum guides about anomalies of the caval vein like interruption of the inferior caval vein (necessitate a trans-hepatic approach); anomalous left superior caval vein with absence of left innominate vein (position the transseptal sheath in right jugular vein); thickness of the atrial septum (to guide the force needed for transseptal puncture); tunnel oval foramen (which needs to be avoided for placing an atrial septal stent). The distance available in the atrial cavity from inferior caval vein entry to the left pulmonary vein entry will guide about the length of the stent to be chosen. Marked stent protrusion into both these veins should be avoided. A thin aneurysmal atrial septum or multifenestrated septum should also pose serious problems for atrial septal stenting, however they are likely to be amenable for blade septostomy or static balloon septoplasty.

Transesophageal versus transthoracic echo

Even though intra-procedural transesophageal echo will improve the quality of images, the esophageal probe will further compress the already compromised space in the hypoplastic left atrium. In some infants, the esophageal probe may compromise the airway too. Intra-procedural transesophageal echocardiographic imaging should be reserved only for difficult situations. Transthoracic imaging from sub-xiphoid windows may disrupt the sterile field, may give poor images in a hypoplastic left atrium and fail to show the oval fossa. But it is a valuable less expensive easily available imaging tool.

Stenting on echocardiographic guidance

Positioning of the stent across the interatrial septum is very crucial to ensure that the atrial septal tissue lies in the middle third of the stent. Echocardiography plays a vital role in this positioning. Once the stent is exposed out of the sheath by withdrawal of the trans-septal sheath into the inferior caval vein, the stent is partially deployed by minimal inflation of the balloon. A partially expanded balloon stent assembly is again carefully interrogated with echocardiogram to ensure that middle third of the stent is aligned to the atrial septum. Once this is confirmed, a near total expansion of the stent is made leaving behind a small waist in the region of atrial septum to create a dog bone or butterfly appearance [Figures 2 and 3]. Hand inflation of the balloon gives more control than use of indeflators.

Stenting on fluoroscopic guidance

Unsheathing the distal half of the stent within the left atrium and partially expanding only the distal left atrial end helps to obtain a stable dog bone or butterfly configuration.[5,15] Then this sheath-stent-balloon assembly is gradually withdrawn till the expanded left atrial end is caught and resisted by the atrial septum. This confirms the location of the middle of the stent against the atrial septum. Once this point is reached, the stent-balloon assembly is fully unsheathed. A small flush of contrast from the sidearm of the transseptal sheath will confirm the location of the stent in relation to the atrial septum. The stent is now expanded progressively till a small waist still remains in the middle.

Size of the atrial communication

The size of the atrial septal stent is chosen based on the hemodynamic indication. In univentricular hearts associated with mitral stenosis, where complete relief of left atrial hypertension will ensure the best hemodynamics for a bidirectional Glenn shunt, a very large atrial stent is needed. Similarly, in post tricuspid bidirectional shunts associated with mitral stenosis, a complete relief of left atrial pressure will reduce the pulmonary vascular resistance significantly. In such instances, the atrial septal stenting should aim at a stent diameter of 8-12 mm. In very small neonates with hypoplastic left heart syndrome, the anatomic size of the left atrium will permit only a 4-6 mm stent [Figure 4]. In addition, if the left atrial pressure is completely relieved in these neonates, the pulmonary vascular resistance, and pulmonary artery pressures will fall dramatically. Once the pulmonary artery pressures fall, the pressures in the aorta perfused by the arterial duct will also fall. This will lead to serious aortic hypotension. So, a moderately restrictive atrial communication that leaves the left atrial pressure about 4-6 millimeters of mercury more than the right atrium is desirable. Fetal atrial septal stenting is done with small coronary stents for the same reasons.[16]

Post-procedural follow-up

After stenting of the atrial septum, even though measurement of left atrial pressure by re-crossing the atrial septal stent with a catheter will give the accurate

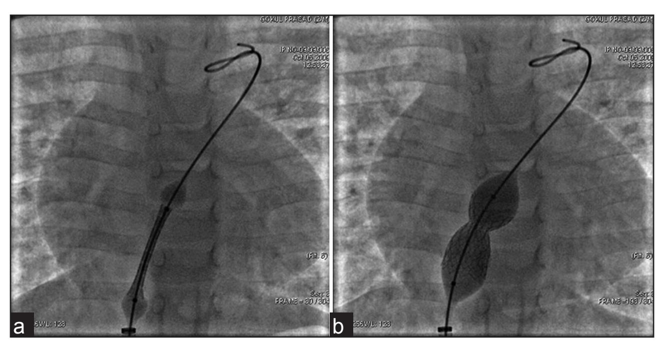

Figure 3: Atrial septal stenting in bidirectional post tricuspid shunt with severe mitral stenosis. After parking the guidewire tip in the most desired location, namely the left pulmonary vein, a stent is positioned on combined echocardiographic and fluoroscopic guidance (a) and then deployed to achieve a butterfly or dog-bone shape (b)

hemodynamic result of the procedure, there is a small possibility of displacement of the stent during such catheter manipulations. So echocardiographic evaluation including a pulse Doppler interrogation of the interatrial gradient is often preferred [Figure 5]. Due care should be exercised during withdrawal of the guidewire from the pulmonary vein for the same reasons. After achieving hemostasis, low dose aspirin is given till the next palliation. On follow up visits, echocardiogram should focus on the location of the stent in relation to the atrial septum, its stability, interference to the pulmonary venous flows, and interference to the inferior caval vein flows [Figure 6]. A longer stent might lead to erosions in the atrium, encroach into the pulmonary or inferior caval veins, or initiate thrombosis within the atrium.

Problems during septal puncture

Perforation of the atrial wall by the septal puncture needle is common due to variations in left atrial anatomy. The thick interatrial septum often requires force to puncture the interatrial septum. As the left atrium is very hypoplastic, the needle tip tends to puncture into the roof of the left atrium or the left atrial appendage immediately after it enters the left atrium. Injection of a small amount of contrast will help to identify the location of the tip of needle. If the pericardial space fills on this injection indicating a left atrial roof puncture, the needle tip is withdrawn a couple of millimeters into the left atrium and a long 0.014” coronary floppy tipped guidewire is advanced into the left atrium [Figure 2]. Once this guidewire coils into the left atrium, the transseptal sheath can be pushed into the left atrium. If the left atrial injury is confined to a 0.021” Brockenbrough needle tip puncture, the resultant pericardial bleed is often contained and is unlikely to lead to tamponade. The puncture orifice closes off and so the atrial stenting can be completed in the same sitting. If the trans-septal sheath is advanced into the pericardial space, the resultant hemopericardium will be uncontrolled and compromise the hemodynamics.

Complications after stenting

In patients where static balloon dilatation or blade septostomy fails to give a reliable interatrial communication, stenting should be done through a separate septal puncture. If stent is deployed on a previously dilated orifice, there is a major risk of embolization. Similarly, embolization is common if stent is deployed in oval foramen of tunnel morphology. An embolized fully expanded stent is often very difficult to retrieve out of the body in these small infants. It should be carefully brought down into the inferior caval vein and expanded between the levels of hepatic veins and renal veins without compromising the flows in both these veins [Figure 7]. Sometimes, the ends of the stent might protrude into the pulmonary veins or inferior caval

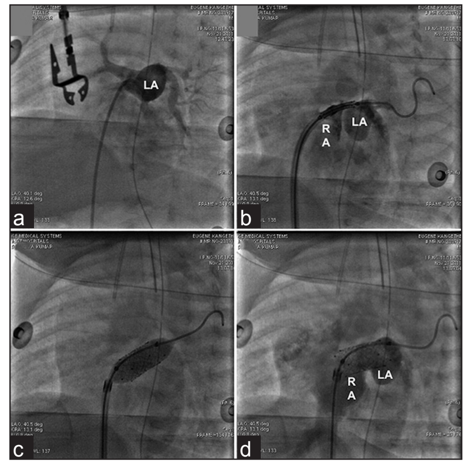

Figure 4: Stenting in neonate with hypoplastic left heart syndrome. Left atrial (LA) angiogram (a) showed hypoplastic left atrium in shallow left anterior oblique projection. After positioning a stent (b) across the interatrial septum, it is deployed (c) to its full diameter. Final left atrial angiogram (d) shows good filling of the right atrium (RA)

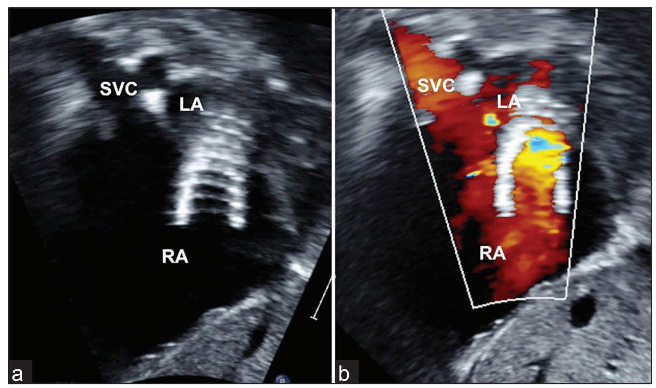

Figure 5: Subxiphoid short axis echocardiogram after atrial septal stenting (a) shows stable stent position across the interatrial septum. Color flow Doppler imaging (b) shows laminar flows across the stent. Repeated catheter entry into left atrium is avoided after stent to prevent embolization. RA-right atrium, LA-left atrium, SVC-superior caval vein

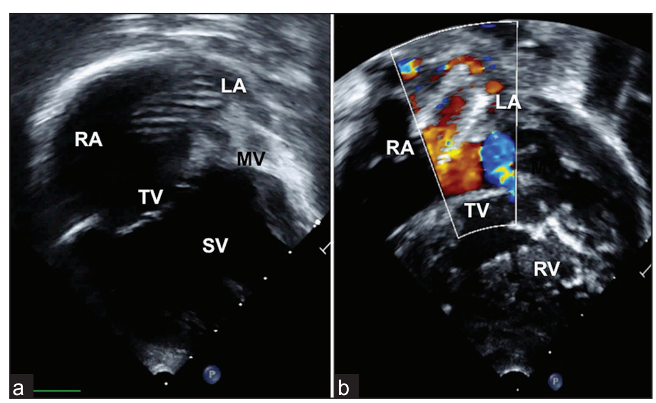

Figure 6: Echocardiographic followup after atrial septal stenting. Panel a shows atrial septal stenting in congenital hypoplastic mitral valve in double inlet left ventricle before univentricular surgical palliation. Panel b shows hypoplastic left heart syndrome with mitral atresia, dilated hypertrophied trabaculated right ventricle. RA-right atrium, LA-left atrium, TV-tricuspid valve, MV-mitral valve, RV-right ventricle, SV-single ventricle

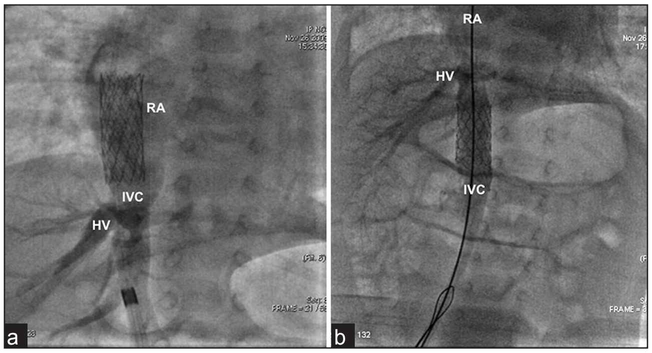

Figure 7: Stent embolization (a) into the right atrium (RA) is seen after stenting a tunnel form of oval foramen in univentricular heart. The expanded stent was withdrawn (b) into the inferior caval vein (IVC) below the level of hepatic veins (HV) and fully expanded to secure it

vein; however, it may not cause hemodynamic problems. Thrombus formation on these stents is rare and possibly prevented by low dose aspirin.

Atrial septal stenting in acquired heart diseases

In severe pulmonary arterial hypertension with right ventricular failure, atrial septal communication will improve cardiac index (by increasing left ventricular preload), functional class, and may even prolong survival. Balloon dilated communications may close off on follow-up and lead to recurrence of syncopal episodes, thereby needing repeated interventions on this sick subset of patients. Stenting is advocated in patients with syncope; refractory or intolerant to pulmonary vasodilators, and as bridge to transplant.

SUMMARY

Atrial septal stenting is done in selected congenital heart diseases where left atrial decompression, inter-circulatory mixing, and maintenance of cardiac output are dependent on the size of the atrial septal defect. The size of the atrial septal communication will depend on the age of the patient, hemodynamic lesion, and whether partial or total left atrial decompression is desired. Embolization of the stent is the major bottleneck of the procedure and this is avoided by dog bone or butterfly configuration of the stent. This configuration is obtained by either echocardiographic or fluoroscopic guidance. Stenting should be avoided in tunnel oval foramens as they offer very little grip on the stent and lead to embolization. For the same reasons, stenting should be never done after a failed blade or balloon septostomy in the same septal orifice. A new septal puncture will give the best bed for deploying an atrial septal stent.

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