Chapter 34
Creating an Interatrial Communication

Derize E. Boshoff and Marc H. Gewillig

The presence of an interatrial shunt may be important to augment cardiac output in obstructive lesions of the right side of the heart, to enhance mixing in patients with transposition of the great vessels, to off-load the right side of the heart in pulmonary vascular obstructive physiology, to relieve left atrial hypertension in left-sided obstructive lesions, and to decompress the right atrium in postoperative right ventricular failure. With the use of extracorporeal membrane oxygenation for circulatory support, an interatrial communication is necessary to relieve left atrial hypertension from the nonejecting left heart, and in those children with a failing Fontan circulation, an adequate interatrial communication may lessen systemic venous hypertension, improve systemic perfusion, and perhaps relieve sequelae such as protein-losing enteropathy. Rashkind balloon atrial septostomy, described in 1966 in patients with transposition of the great arteries, was the first percutaneous atrial septostomy [1]. Few transcatheter techniques have been developed over the years

D.E. Boshoff (✉) • M.H. Gewillig
Department of Pediatric Cardiology, University Hospital Leuven,
49 Herestraat, Leuven 3000, Belgium
e-mail: derize.boshoff@uzleuven.be;
marc.gewillig@uzleuven.be

G. Butera et al. (eds.), *Cardiac Catheterization for Congenital Heart Disease: From Fetal Life to Adulthood*,
DOI 10.1007/978-88-470-5681-7_34,

to create or enlarge an interatrial communication. These include balloon atrial septostomy, blade atrial septostomy, static balloon dilation of the septum, and radiofrequency perforation or transseptal puncture of the septum, followed by one of the above procedures. These techniques provide a temporary solution; for longer-lasting mixing/relief of obstruction, stent implantation in the septum may provide a more durable solution.

34.1 Anatomy of the Oval Fossa and Surrounding Structures

The key to a successful atrial septostomy is knowledge and understanding of the anatomy of the fossa ovalis and the surrounding landmarks.

The interatrial septum is bounded posteriorly by a fold of pericardium between the atria, superiorly by the vena cava superior, anterosuperiorly by the noncoronary sinus cusp of the aortic valve, anteriorly by the septal tricuspid annulus, anteroinferiorly by the coronary sinus ostium, and inferiorly by the vena cava inferior. The interatrial portion is relatively small and its most prominent feature is the fossa ovalis, comprising an average of 28 % of the total septal area. During fetal and neonatal life, the valve of the fossa ovalis is a paper-thin, delicate, and translucent membrane. With increasing age, however, the valve becomes thicker, tougher, and more opaque, due to deposition of collagen and elastin. Because of hemodynamic streaming within the right atrium during fetal life, the poorly oxygenated blood from the vena cava superior is directed toward the tricuspid valve, while well-oxygenated placental blood from the vena cava inferior is directed via the Eustachian valve toward the fossa ovalis and into the left atrium. As a result of this orientation of the venae cavae, transseptal access is much easier via the vena cava inferior, in contrast to right ventricular biopsies, which can be more readily performed via the vena cava superior.

Occlusion of the femoral veins may therefore be considered as an anatomical limitation for transseptal access. The umbilical vein is a good alternative in the newborn baby, but if obstructed, the transhepatic access can be used safely even in small infants. The advantages of this route include a better angle to access the atrial septum and the possibility of using larger sheaths in small children without vascular damage.

34.2 Catheterization Procedure: General Principles

The procedure is typically performed under general anesthesia. The exception to this rule is routine atrial septostomy in newborn babies performed in the neonatal intensive care unit under echocardiographic guidance. Prophylactic antibiotics and heparin sulfate (100 units/kg) should be given intravenously. In patients who require mechanical or radiofrequency (RF) transseptal access, heparin should be given only after entering the left atrium. The creation of an atrial communication should include surgical and circulatory support backup. The surgical backup does not necessarily mean a standby operating room but rather the availability of surgeons and anesthesiologists who can manage neonates and infants in case of complications from the procedure.

34.3 Imaging Techniques

34.3.1 Fluoroscopy

Biplane fluoroscopy is preferred for performing an atrial septostomy, with the only exception being routine atrial septostomy in newborn babies with simple transposition of the great arteries.

It is of particular importance in small patients or conversely in larger patients with either a very large or very small atrium, a large dilated aortic root, no vena cava inferior access to the atrial septum, or any abnormal cardiac chamber or great vessel positional abnormalities. Several different angiographic projections have been described to best visualize the interatrial septum during transseptal procedure (discussed in detail in Chap. 15).

34.3.2 Echocardiography

Echocardiographic imaging has greatly improved the success and safety of transseptal interventions.

Transthoracic echocardiography (TTE) may permit visualization of the interatrial septum and the adjacent structures, but its role in guiding complex transseptal catheterization (i.e., stent implantation) is limited due to poor image quality, difficulty to identify the fossa ovalis correctly, and disruption of the sterile field.

The fossa ovalis can be accurately located using intracardiac echocardiography (ICE), but it has limitations as sheath size, additional puncture in the femoral vein, possible longer procedural time, and significantly higher costs.

Transesophageal echocardiography (TEE) is probably the modality of choice in addition to fluoroscopy, particularly when visualizing a specific area of the fossa ovalis to be punctured, the thickness of the septum at that point, and the degree of anterior-posterior direction of the intended puncture and certainly in the case of complex (congenital) anatomy when stent implantation is performed. In small infants, the use of the higher profile biplane or multiplane pediatric TEE probes may cause airway and even left atrial compression, which may distort the underlying septal anatomy and limit even further the already restricted space in the left atrium for transseptal procedures.

Limited reports suggest that the 8-French AcuNav (ACUSON Acunav, Siemens Medical Solutions, USA) probe can be used transesophageally in small infants. Although the AcuNav is a monoplane probe and does not have an attached thermistor, the quality of the pictures seems to be sufficient and thermal damage in the esophagus did not seem to be an issue in these limited reports.

34.4 Balloon Atrial Septostomy

Balloon atrial septostomy (BAS) should be available in every institution that cares for infants with congenital heart disease.

Because of septal thickening with age, it is usually not consistently effective beyond the neonatal period. Emergency BAS is performed in any infant with simple transposition of the great arteries who exhibits evidence of acidosis as a result of inadequate interatrial mixing.

It is also indicated in all infants with simple transposition of the great arteries who are younger than 1 month of age with a restrictive interatrial communication and not otherwise scheduled for immediate surgery.

It may also be indicated for palliation in neonates with other congenital heart lesions in whom all systemic, pulmonary, or mixed venous blood must traverse through a restrictive interatrial communication to return to the circulation.

34.4.1 Balloon Catheters

Balloon atrial septostomy (BAS) catheters are available from various manufacturers and in different designs. Currently, there are four different catheters that can be used for this purpose:

1. *The Miller-Edwards catheter (Edwards Lifesciences)*
   This is a single-lumen catheter with a 5-Fr shaft but requires a 7-Fr sheath. It has a 35° hockey stick angle 2 cm from the tip, which allows easy entry into the LA. The fairly compliant

latex balloon is capable of accepting 4–5 ml of fluid. At that volume, the diameter of the balloon sphere is 17–18 mm. Due to the relatively high compliance, large balloon inflations are often required to successfully perform a septostomy, which is a considerable disadvantage (especially in small infants <3 kg, or a small LA).

2. *The Rashkind balloon catheter (USCI-CR Bard)*
   This septostomy catheter has a recessed, low-profile balloon and can be introduced through a 6-Fr sheath. The balloon accepts 1.5 ml of contrast to give a balloon diameter of 12–13 mm. Larger volumes will only elongate the balloon without increasing the diameter.
3. *The Fogarty (Paul) balloon catheter (Edwards Lifesciences)*
   Introduced via a 6-Fr sheath.
4. *The NuMED Z-5 Atrioseptostomy catheter (NuMED)*
   This is the only catheter with an end hole that enables the operator to advance it over a guidewire and to confirm position by injecting contrast in the left atrium. It is available with balloon sizes of 1 ml (9 mm diameter) and 2 ml (13.5 mm diameter) and can be passed over a 0.014/0.018-in. wire (5-Fr/6-Fr sheaths). The noncompliant nature of the Z-5 septostomy catheter and its relatively small size offer distinct advantages when performing BAS in patients with a small left atrial size (i.e., HLHS). Of note is that a radiopaque marker is located in the midportion of the balloon. However, the wrapped balloon will extend a fair amount beyond the end of the catheter shaft, and one has to be very careful when advancing this balloon to avoid pushing the fairly stiff tip against the left atrial wall or appendage, which can easily induce atrial tachycardia [2].

34.4.2 Procedure

Access is obtained from either the umbilical vein or the femoral vein by use of an appropriate-sized sheath (5–7 French, depending on the type of septostomy catheter to be used). If the procedure is done in the catheterization laboratory and the baby is stable, routine hemodynamic assessment may be performed, followed by the septostomy. When using the umbilical venous approach, the progress of the catheter through the ductus venosus can be monitored either by fluoroscopy (in which case the catheter passes from the right of the midline superiorly toward the right atrium in the AP projection and from front to back in the lateral projection) or by cross-sectional echocardiography. It may sometimes be difficult to pass the catheter into the VCI due to stenosis or closure of the ductus venosus. In this case, a 0.018″ guidewire and 4-French end-hole catheter combination can be introduced into the umbilical vein and then manipulated into the right atrium. Thereafter, an appropriate-sized sheath can be used to introduce the septostomy catheter. When using a sheath in the umbilical vein, it must be kept in mind that the tip of the sheath is often inside the RA and may impede withdrawal of the inflated balloon across the septum if not withdrawn into the ductus venosus before performing the septostomy. Once the balloon is positioned in the left atrium and the position is confirmed (by fluoroscopy and/or echocardiography), the balloon is inflated with the appropriate volume of saline/contrast mixture (80/20 %) while holding the balloon against the atrial septum (to prevent passage across the mitral valve).

The stopcock is closed and the balloon advanced 1–2 mm of the atrial septum and then jerked/pulled briskly to the right atrial/vena cava inferior junction. The balloon is subsequently advanced promptly to the mid right atrium and deflated as quickly as possible. The balloon must be watched on fluoroscopy or echocardiography during inflation: if it does not retain a perfectly circular shape even at its highest inflation volume, it is probably not free in the atrium and must be deflated and repositioned. Care must be exercised as to how vigorously the balloon is pulled into the inferior vena cava. This process is repeated at least once until there is no resistance to passage of the full balloon across the defect. A gradient across the septum may be measured, and if still significant, a balloon atrial septostomy may be repeated as above. Alternatively, echocardiography along with Doppler assessment of the residual gradient may be used to determine the adequacy of the septostomy.

34.4.3 Tips for Crossing the "Difficult" Septum

A variety of techniques can be used to advance the septostomy catheter across the interatrial septum. Direct advancement of the pre-shaped catheter is successful in most cases. In some patients, advancing a sheath across the interatrial septum may facilitate passage of the septostomy catheter. The Cordis 6-FR BRITE TIP sheath (Cordis Corp., Miami, FL) has a sufficiently smooth transition to pass over a 0.018-in. guidewire into the left atrium. It is important though to pull back the sheath sufficiently into the vena cava inferior, prior to performing the BAS. If all techniques fail, advancing a low-profile balloon, such as the NuMED Tyshak Mini (NuMED, Hopkinton, NY), across the interatrial septum may allow predilation of the interatrial communication to subsequently allow passage of the septostomy catheter.

34.4.4 Intact Interatrial Septum

Perforation of the interatrial septum may be required whenever the interatrial septum is intact or the existing interatrial communications are unsuitable for BAS (superior or inferior location). The use of the standard Brockenbrough needle for transseptal puncture in patients with complex anatomy or a small left atrium (HLHS and variants) may be rather cumbersome, with the potential risk of atrial perforation. The Nykanen radiofrequency (RF) perforation wire and the 180-cm 0.035-in. outer diameter coaxial injectable catheter (both Baylis Medical Corporation, Montreal, CA) can be controlled and appropriately directed using a Judkins right coronary catheter. This is particularly beneficial in patients with a small left atrium or unusual anatomy.

34.5 Blade Atrial Septostomy

In infants older than 1 month of age, and certainly in older children, the atrial septum is usually too tough or thick for a simple BAS to tear the septum. The indications for blade atrial septostomy are the same as considered for a balloon septostomy or for surgical atrial septostomy that otherwise would be needed in the older infant. Blade septostomy catheters (Cook, Bloomington, IN) are available with three blade lengths: 1.0, 1.34, and 2.0 cm. The two smaller blades (the PBS 100 and 200) are available on a 6-French catheter, and the 2.0 blade (the PBS 300) is on an 8-French catheter. Both blade catheter sizes require a sheath one size larger than the catheter for smooth introduction. The blade is controlled by a wire that has a moveable "handle": if the wire is fully retracted so that the blade is inside the catheter shaft, the handle may be locked against the hub, preventing inadvertent blade protrusion. A side port is available to flush the catheter with saline (or contrast); the direction of the port (off the side of the catheter) is roughly the same as the direction of the curve and of the blade when it is protruded. The blade should always be tested outside the patient to be sure it opens and closes fully without resistance. The blade catheter is advanced through the previously placed long Mullins sheath into the left atrium, and the sheath is then withdrawn well into the vena cava inferior. The blade is then opened carefully in the left atrium while it is continuously observed on fluoroscopy (and ideally also under TEE guidance). The tip is directed anteriorly and either to the patient's right or left side. In contrast to the balloon septostomy, the blade catheter is withdrawn slowly in a controlled maneuver. Resistance may be quite considerable, so bracing one's hands against the patient's leg (and pulling with the fingers) during the maneuver may prevent sudden retraction of the open blade down the vena cava inferior. If the septum proves too rigid to cross with a fully opened blade, the opening angle should be adjusted to 45–60° before pulling across and then repeated with a fully opened blade. Once the blade has crossed the septum, the catheter should be slightly advanced and the wire withdrawn to retract the blade back inside the catheter. The blading is repeated at least four times while changing the angle of extension of the blade as necessary and changing the blade direction from side to side until there is no further resistance to withdrawal of the fully opened blade catheter. The blade septostomy is followed by a balloon septostomy (standard BAS or static balloon dilation). Blade septostomy should probably be avoided though in patients with complex anatomy and small left atrial size, and the combination of cutting balloon septostomy and static balloon septostomy is likely a safer alternative in patients with a small left atrial size.

34.6 Cutting Balloon Septostomy

With the availability of larger cutting balloons of ≤8 mm in diameter (Boston Scientific, Boston, MA), the combination of static cutting balloon septoplasty, followed by the use of larger diameter static balloons or standard balloon atrial septostomy, has become a valuable alternative to blade atrial septostomy in patients with a thickened interatrial septum. It is suggested that the microsurgical blades of the cutting balloon allow controlled tearing of the septal wall rather than stretching of the thickened interatrial septum, as seen with static balloon dilation alone. Rotation of the cutting balloon followed by repeat inflations may tear the interatrial septum in different locations and improve the response to static balloon septoplasty. The smaller the preexisting septal defect, the higher the likelihood that the use of a cutting balloon will achieve an adequate result. If the existing interatrial communication is "stretchable" (i.e., floppy valve), cutting balloon dilation will be inefficient. In this situation, it may be better to perform a transseptal puncture and start with a new diminutive opening to obtain a better result with cutting balloon septoplasty. The cutting balloon catheter (typically 4–8 mm) is advanced through a 6- or 7-French (short/long) sheath over a 0.014-in. coronary angioplasty wire or a 0.018-in. guidewire (Roadrunner, Cook) positioned in the left upper pulmonary vein or alternatively curled in the body of the left atrium.

34.7 Static Balloon Septostomy

This modality can be used primarily or after blade septostomy or cutting balloon septoplasty. The balloon dilation is performed with a high-pressure balloon (Fig. 34.1). Balloon diameter will depend on patient/atrial size and underlying cardiac anomaly.

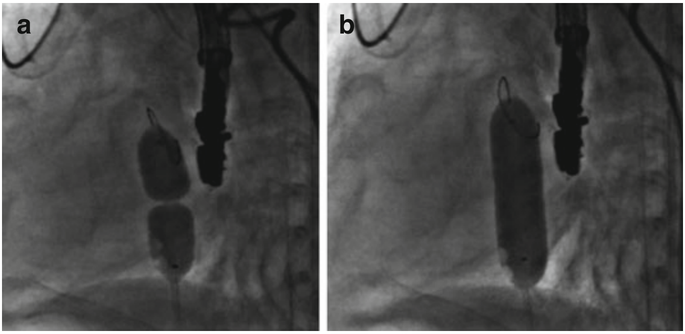

Fig. 34.1 Static balloon dilation of restrictive atrial communication (**a**) 12 mm balloon inflated at mild pressure delineating the small atrial communication (**b**) full inflation stretches-tears the septum.

34.8 Stent Implantation in Congenital Heart Defects: Nonrestrictive Technique

A restrictive interatrial communication in patients with univentricular anatomy significantly affects surgical outcomes. In patients with univentricular hearts, wide-open atrial communication leads to lower pulmonary artery pressure, which is one of the most important factors influencing the success of bidirectional Glenn and Fontan operations. In some patients, recurrence of restricted interatrial communication can be observed despite initially successful interventional or surgical creation of unrestrictive interatrial communication. Atrial stent septostomy can provide a reliable long-lasting restrictive or nonrestrictive interatrial communication.

34.8.1 Procedure

After access has been obtained in the left atrium, a wire should be positioned in a pulmonary vein and an appropriate-sized long sheath advanced over the wire with the tip across the atrial septum. Premounted balloon-expandable stents are preferable in this setting although self-expandable stents have been used with success in some patients. The stent diameter will depend on the age and size of the patient and the type of congenital anomaly (especially atrial size), aiming to provide an unrestrictive and potentially durable flow through the interatrial septum for several months. One of the crucial facts is to avoid implanting too long stents due to the risk of atrial erosion, thrombus formation, and obstruction of the pulmonary veins. The stent should be long enough though to allow adequate stabilization within the interatrial septum, minimizing the risks of embolization due to movement during inflation or due to foreshortening after expansion. We advise using the technique of sequential stent flaring to facilitate accurate stent positioning. The stent is advanced through the long sheath into the left atrium. Half of the stent is exposed by pulling back the sheath and the balloon is inflated in the left atrium, expanding the distal half of the stent. Pressure in the balloon is maintained using a stopcock. Next, the entire system is firmly pulled back against the atrial septum. The pressure in the delivery balloon is slightly released, allowing the right atrial portion of the stent to be unsheathed. The balloon is then fully inflated, opening the proximal portion of the stent. The deflated balloon should be removed carefully out of the stent into the long sheath, avoiding stent dislodgment. We advise against crossing the newly implanted stent with a catheter unless certainty of adequate fixation. Gradients and flow across the interatrial septum should be assessed using TTE or TEE (Fig. 34.2). In contrast to conventional balloon atrial septostomy, stent implantation requires anti-aggregation treatment (acetylsalicylic acid 2–5 mg/kg/day) to prevent thrombus formation.

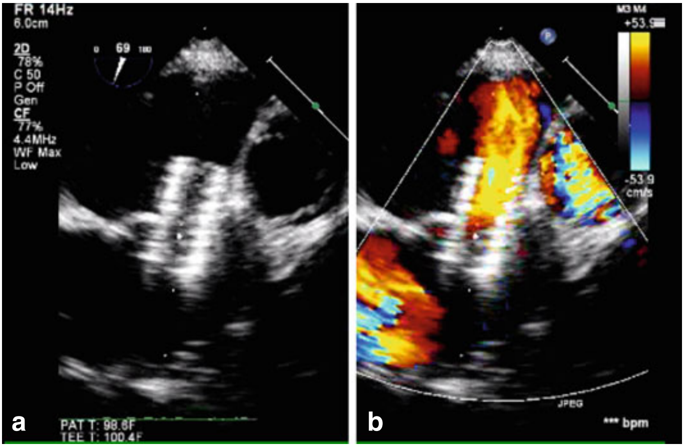

Fig. 34.2 TEE of stent across atrial septum (**a**) a Genesis 1910 stent is nicely positioned across the atrial septum (**b**) color flow mapping shows right-to-left shunt across the stent

34.9 Stenting of the Interatrial Septum: Restrictive Technique

34.9.1 Pulmonary Arterial Hypertension

Atrial septostomy for severe pulmonary arterial hypertension (PAH) improves cardiac index and functional class by the creation of a right-to-left atrial shunt and may even improve the survival in some patients. The presence of this iatrogenic shunt decompresses the failing right ventricle and improves left ventricular preload and thus cardiac index. Early series reported a high mortality, largely caused by difficulty in achieving accurate control of the size of the atrial shunt. Improvements in patient selection and septostomy techniques (i.e., sequential balloon dilation) have increased the safety of the procedure; however, a high spontaneous closure rate is observed after balloon dilation, necessitating repeated procedures in an already critically ill patient group. The recent evidence-based treatment guidelines for PAH list the indication for the atrial septostomy procedure as Class 1C, generally limited to specialized centers and reserved for patients with recurrent syncope and those who are refractory to, or intolerant of, medical therapy or as a bridge to transplantation. In contrast with balloon septostomy, restrictive stenting of the interatrial septum with the use of a diabolo-shaped (bow tie or dog bone stent) allows for a predictable and long-lasting interatrial shunt in these patients. The fenestration technique currently used in our unit has been adapted from [3], who described a small mixed series of primary PAH patients and patients with a failing Fontan circulation. A venous sheath up to 12 Fr is placed into the right femoral vein, followed by a puncture of the interatrial septum with a Brockenbrough needle.

34.9.1.1 Stent Preparation

A loop of 3–5 mm diameter is created using a set of temporary epicardial pacing wires. The needle ends are removed, including the distal 5 cm length of isolative coating, allowing making a low-profiled tight knot with bare metal wire. The two wires are tied together to provide a length of about 90 cm, allowing the wire to leave the sheath at the operators end. Using the bare end of the wire, a secure double knot is formed over a 10–14-French dilator. The resultant loop is then placed over the midportion of a standard 15-mm valvuloplasty balloon catheter. A standard stent (PALMAZ GENESIS stent 1910, Cordis Corporation, Miami Lakes, FL) is gently dilated with the help of the tapered end of the 10–14-French dilator. The stent is then mounted on the valvuloplasty balloon, taking care that the loop created from the pacing wire is placed accurately in the center of the balloon and the stent (Fig. 34.3). The stent is then manually crimped, and its stability tested.

34.9.1.2 Stent Deployment

The mounted stent is delivered through the long sheath, securing the end of the temporary pacing wire. The stent is then deployed using the technique of sequential stent flaring, as described above (Fig. 34.4). After the stent has been deployed in diabolo across the septum, the balloon (with the metal-knot wire) is removed. We gradually increase the size of the fenestration until arterial saturation has decreased down to 80–85%.

34.9.2 Fontan Circulation

Secondary fenestration of a failing Fontan circulation is a valuable technique to improve the hemodynamic condition of the

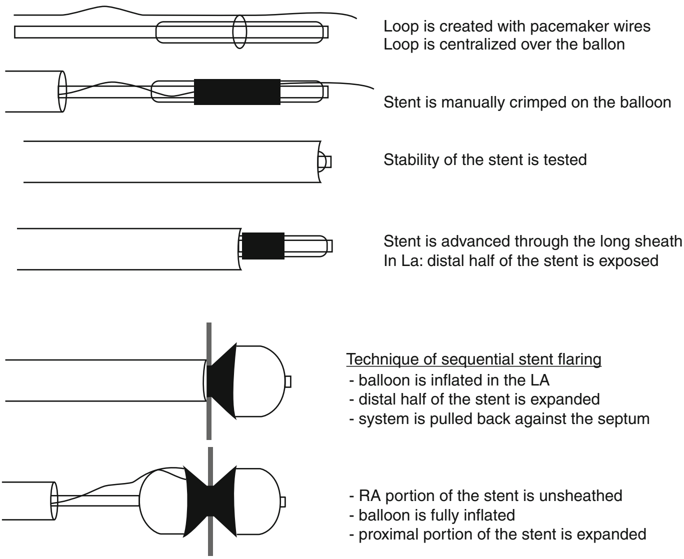

Fig. 34.3 Cartoon with various steps for a diabolo stent

patient. The fenestration is created to allow a restrictive right-to-left shunt, decreasing the systemic venous pressure and congestion, with increase in cardiac output, but at the expense of arterial desaturation. However, cyanosis is better tolerated than low cardiac output with congestion [4]. Fenestrating the extra-cardiac Fontan circuit may be more challenging, due to separation of the different wall layers during needle puncture and sheath placement [5]. The optimal perforation site in the extra-cardiac Fontan conduit is the point that has the most acute angle coming from the inferior (exceptionally the superior) caval vein and which is in contact with the atrium. Gore-Tex conduits are poor conductors and are therefore not vulnerable for RF perforation. Puncturing the conduit with a Brockenbrough needle may require considerable force and consequently adequate

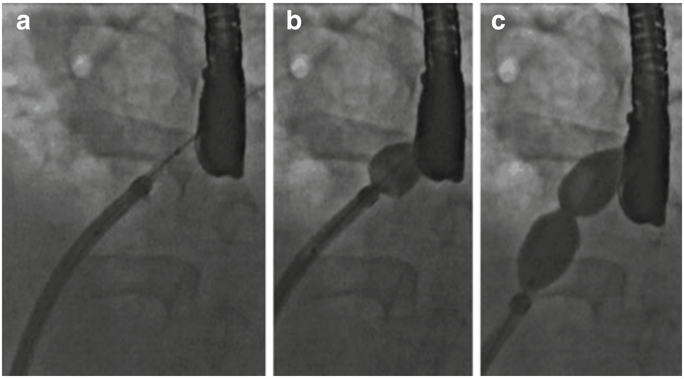

Fig. 34.4 Deployment of a 1910 Genesis stent (**a**) 10F sheath into left atrium, stent is partially uncovered (**b**) inflation of 15 mm balloon results in flaring of distal end of the stent (**c**) after pulling whole system against the septum, the sheath is pulled back to uncover the RA end, and further inflation of the balloon results in diabolo shape of the stent across the atrial septum

immobilization of the patient. Currently we prefer puncture of the inferior caval vein just below the conduit. Once the Gore-Tex or caval wall is crossed, the point of the needle will be in the atrial wall. By giving a small contrast injection, the atrial wall can be tagged and some overflow may be observed in the pericardial space. The needle should then be further advanced until it pops through the atrial wall (position confirmed by small contrast flush). A 0.014-in. coronary wire is then advanced through the needle until well within the atrium (preferably the left upper pulmonary vein). Advancing the dilator and sheath over the Brockenbrough needle may again require considerable force and wringing of the sheath. It is sometimes necessary to predilate the Gore-Tex conduit with a 4- or 5-mm cutting balloon before the sheath can be advanced through the Gore-Tex. After crossing the detached pericardial space, the sheath should be advanced through the atrial wall until well within the atrium before the needle and dilator are withdrawn. The techniques for stent preparation and implantation are identical to the method described for restrictive stenting in patients with PAH. Sequential stent flaring allows for re-approximation of the different layers during stent deployment, creating a predictable restrictive right-to-left shunt.

34.10 Complications

Complications of balloon atrial septostomy include tears to the left atrium, pulmonary vein, and right atrium, as well as atrial dysrhythmias (usually transient). Atrial septal interventions in patients with HLHS can pose a considerable technical challenge, and procedure-related mortality has been reported to be as high as 15 %. In patients with a thick interatrial septum, even a partially inflated balloon may not tear the interatrial septum, causing a shearing force on the pulmonary veins, leading to pulmonary vein avulsion and death in the treated patient. Complications inherent to atrial septal puncture are cardiac perforation and puncture of an inappropriate atrial septal site. Occasionally, the valve is extremely floppy so that when pushed with the tip of the catheter, it may even extend to the lateral wall of the LA, risking exit into the pericardial space when the "septum" is punctured. Prompt recognition and management of cardiac tamponade are essential to minimize the mortality in these patients.

34.11 Conclusions

Creation or enlargement of interatrial communications can be achieved using a variety of transcatheter techniques including transseptal needle puncture or RF perforation, balloon septostomy, blade septostomy, and stent implantation. The procedure can improve hemodynamics acutely in a variety of compromised circulations or provide effective palliation until definitive surgery can be attempted.

References

1. Rashkind WJ, Miller WW (1966) Creation of an atrial septal defect without thoracotomy. A palliative approach to complete transposition of the great arteries. JAMA 196(11):991–992
2. Holzer RJ, Wood A, Chisolm JL et al (2008) Atrial septal interventions in patients with hypoplastic left heart syndrome. Catheter Cardiovasc Interv 72(5):696–704
3. Stumper O, Gewillig M, Vettukattil J et al (2003) Modified technique of stent fenestration of the atrial septum. Heart 89(10):1227–1230
4. Gewillig M, Goldberg DJ (2014) Failure of the Fontan circulation. Heart Fail Clin 10(1):105–116
5. Gewillig M, Boshoff D, Delhaas T (2006) Late fenestration of the extracardiac conduit in a Fontan circuit by sequential stent flaring. Catheter Cardiovasc Interv 67(2):298–301