Chapter 15
Transseptal Access

Chad Kliger and Carlos E. Ruiz

15.1 Introduction

Transseptal (TS) puncture of the left atrium was first described in 1959 as a new, alternative method in accessing the left heart for the assessment of patients with acquired or congenital heart disease [1]. With the increasing volume of structural heart procedures and growing number of congenital heart patients reaching adulthood, the operator needs skills to safely perform a TS puncture.

C. Kliger, MD, MS
Department of Cardiothoracic Surgery, Division of Structural and Congenital Heart Disease Lenox Hill Heart and Vascular Institute – North Shore/LIJ Health System, 130 East 77th Street, 4th Floor Black Hall, New York, NY 10075, USA
e-mail: ckliger@nshs.edu

C.E. Ruiz, MD, PhD (✉)
Department of Cardiothoracic Surgery, Division of Structural and Congenital Heart Disease Lenox Hill Heart and Vascular Institute – North Shore/LIJ Health System, 130 East 77th Street, 9th Floor Black Hall, New York, NY 10075, USA
e-mail: cruiz@nshs.edu

G. Butera et al. (eds.), *Cardiac Catheterization for Congenital Heart Disease: From Fetal Life to Adulthood*,
DOI 10.1007/978-88-470-5681-7_15, © Springer-Verlag Italia 2015

15.2 Understanding Transseptal Anatomy

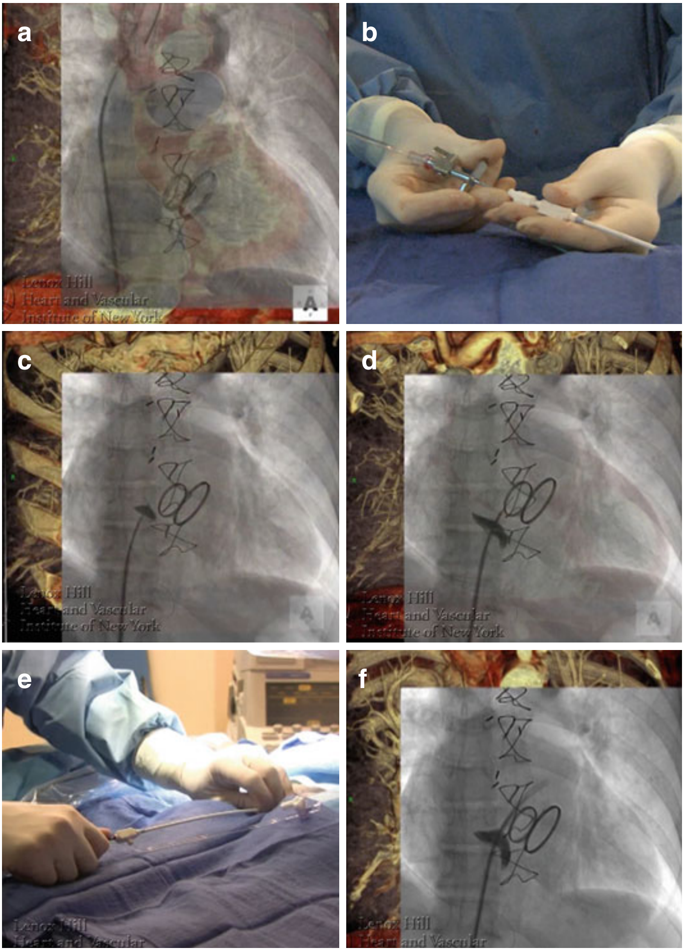
A thorough knowledge of both atria, the *interatrial septum*, and adjacent cardiac structures is crucial for TS heart catheterization [2]. A majority of the atrial septation is formed by infolding of the right and left atrial walls (interatrial groove), with puncture outside the *fossa ovalis* valve (FO) and adjacent margins of its muscular rims (limbus), leading to perforation. The interatrial septum (IAS) is bounded posteriorly by a fold of the pericardium between the left and right atria, superiorly by the superior vena cava (SVC), anterosuperiorly by the noncoronary sinus of the aortic valve, anteroinferiorly by the coronary sinus, and inferiorly by the IVC. The supero-posterior rim is often referred to as the septum secundum. The aortic mound is located anterior and superior to the FO, overlying the aorta; posterior to the aortic mound is the transverse sinus or retroaortic space. More caudally, the pyramidal space constitutes the posterior septum where the right-sided pulmonary veins and their pericardial reflections forming the oblique sinus are located.

15.3 Transseptal Technique

The technique of *TS puncture* has a multitude of steps with variations made based on operator preference and patient-related factors (Fig. 15.1). First, a 0.032 or 0.035 in. J-tipped 135 cm guidewire is advanced to the SVC and a 8 F 62 cm-long sheath (SL or Mullins) placed. The guidewire is removed, leaving the sheath with its dilator locked in place. The dilator is bled back and flushed with a syringe to avoid thrombus or air introduction into the right atrium. Next, a 71 cm TS needle (standard Brockenbrough, BK, with 19° angle), selected to fit the length of the sheath, is attached to a manifold that allows for pressure monitoring, flush/discard, and contrast injection.

The needle is introduced while continuously flushing and is gently advanced through the sheath allowing it to rotate freely within the dilator. If resistance is met, especially at the location of the inferior vena cava/pelvic brim, the needle stylet should be reinserted to prevent piercing through the dilator/sheath. The needle tip must be kept within the lumen of the dilator, maintained approximately two fingerbreadths (1–2 cm) away from the sheath hub. Once the transeptal needle is juxtaposed to the tip of the dilator, the entire system is positioned at the 3–6 o'clock locations – both the sheath with sideport and needle indicator arrow pointed in the same direction. Typically the 4–5 o'clock location (45° from the horizontal plane) is most desired with 3 o'clock being directed toward the patient's left side (Fig. 15.2). The IAS is a posterior structure typically located at the 4–5 o'clock location; the aorta or retroaortic/transverse sinus is located at the 1–3 o'clock locations and should be avoided.

Thereafter, the SVC/RA pressure tracing is recorded and the system withdrawn all together toward the IVC, without changing the relative distance between the sheath and needle. Upon descent from the SVC to FO, the system usually encounters two leftward jumps: first at the SVC/RA junction and second from the muscular IAS (in the region of the aortic mound) into the FO. The TS tip should subsequently engage the FO, with the apparatus advanced slightly to firmly contact and tent the septum. A loss of RA pressure is typically noted and 3–5 cc of contrast gently injected to stain the IAS. Once position is confirmed, the sheath/dilator is firmly anchored and the TS needle is briskly advanced, puncturing the septum. The transducer should reveal LA pressure, and additional contrast can be injected and oxygen saturation performed to confirm LA positioning. If LA pressure tracing is not noted, change the scale to assess for aortic pressure. Staining of the pericardium or aorta verifies inadvertent pericardial or aortic puncture. Until confirmation is made, the sheath/dilator should not be advanced.



The entire system is then advanced about 1 cm across the IAS, allowing the dilator to cross the septum. The dilator is disconnected from the sheath, and the needle/dilator is turned in a counterclockwise rotation, toward 12–1 o'clock, bringing the entire system anteriorly toward the center of the LA away from the posterior wall. The dilator/needle is fixed and the sheath advanced into the LA. Successively, the sheath is fixed and the dilator/needle removed slowly to avoid introducing air into the sheath. In addition, aspiration of the TS sheath can introduce air through the valve and is not recommended. Passive back bleeding with the sheath port positioned below cardiac level will allow for appropriate de-airing of the system. The sheath can then be flushed and the patient appropriately anticoagulated to achieve therapeutic ACTs between 250 and 300 ms, further adjusted according to the desired intervention.

Fig. 15.1 Technique of transseptal puncture. (**a**) An 8 F 62 cm-long sheath is advanced over a J-tipped guidewire to the superior vena cava. The guidewire is removed and a 71 cm transseptal (TS) needle introduced under continuous flush. (**b**) With the needle approximately two fingerbreadths (1–2 cm) away from the sheath hub, the entire TS system is positioned at the 4–5 o'clock location and withdrawn caudally until it encounters two leftward jumps: SVC/right atrial junction and muscular interatrial septum. (**c**) TS tip subsequently engages the fossa ovalis (FO), confirmed by contrast injection. (**d**) Needle is briskly advanced puncturing the septum. (**e**) Once needle position is confirmed within the left atrium (LA), the entire system is advanced 1 cm. The dilator is disconnected from the sheath and the needle/dilator is turned toward the 12–1 o'clock location. (**f**) The sheath is advanced over the dilator into the LA and finally the dilator/needle removed. Passive back bleeding of the sheath de-airs the system and the patient is afterward anticoagulated

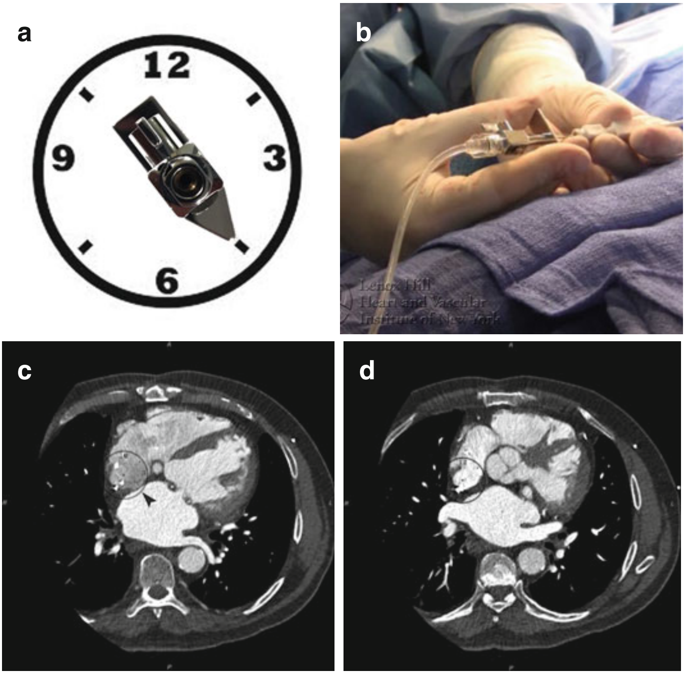


Fig. 15.2 Transseptal needle position. (**a**) The transseptal (TS) needle indicator arrow dictates the location of the needle tip. With the patient on a horizontal plane (3/9 o'clock), the sheath with sideport and indicator arrow are pointed in the same direction to the 4–5 o'clock location (45° from the horizontal plane). The interatrial septum with the fossa ovalis (FO) is typically a posterior structure located at this position. (**b**) Holding of the needle and the TS sheath/dilator requires maintaining the same distance from the distal dilator tip (1–2 cm) and concordant movements of the system. (**c**, **d**) A clockface superimposed on an axial slice of a cardiac CT reveals the location of the FO at 4–5 o'clock and the aortic valve more anterior at the 1–3 o'clock

15.4 Knowledge of Imaging

15.4.1 Fluoroscopy

Traditionally, TS technique has been performed using *fluoroscopy*. The anteroposterior (AP) projection allows for identification of appropriate placement within the mid right atrium and against inadvertent placement into the right ventricle or LA through a patent foramen ovale (PFO). The placement of a pigtail catheter into the noncoronary cusp aids at delineation of the posterior border of the aortic wall, as well as the aortic valve/root. It also provides active arterial blood pressure monitoring during the procedure.

In addition to the AP view, other views should be utilized including right anterior oblique (RAO) at 40–50° and left anterior oblique (LAO) at 30–55° [3] (Fig. 15.3). The location of the TS system within the anterior/posterior axis is evaluated in the RAO view and within the superior/inferior axis in the LAO view. In the RAO projection, the IAS is en face with posterior, superior, and inferior borders identified. The intended site of puncture is halfway between the posterior boundary of the atria and a line drawn extending from the posterior aortic wall, approximately 1–3 cm below the noncoronary cusp. The angle at which the septum is punctured can be visualized with the needle directed away from the field of view. In the LAO projection, a line can be drawn extending from the posterior aspect of the pigtail catheter to the spine at a 45° angle. The intended puncture site is located approximately halfway between these two landmarks along this line with the needle directed to the right in a posterior direction.

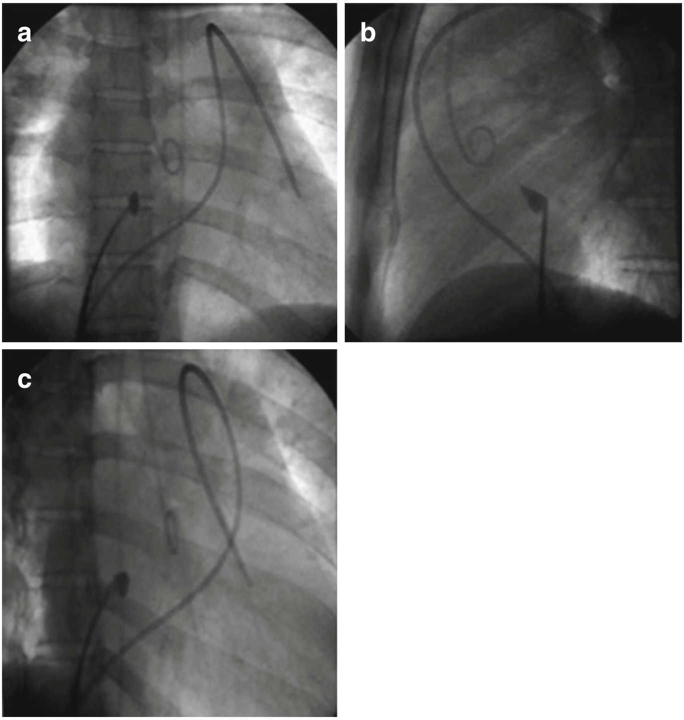


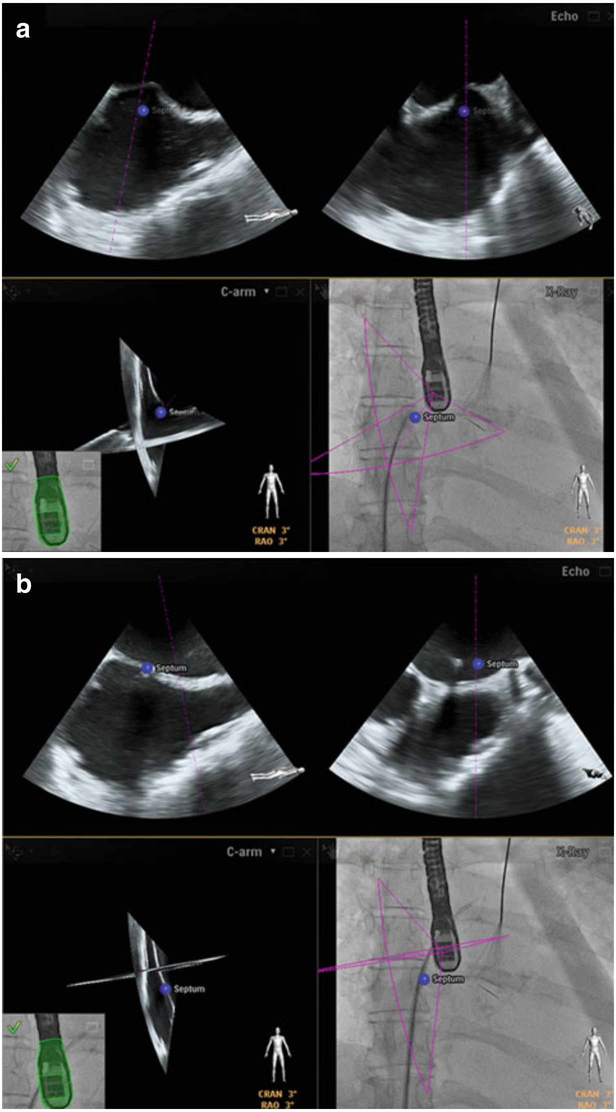
Fig. 15.3 Fluoroscopy for transseptal puncture. (**a**) In the anteroposterior (AP) view, the pigtail can be noted placed into the noncoronary aortic valve cusp, identifying the posterior border of the aortic wall and aortic root. A balloon-tipped catheter is also visualized within the right ventricular outflow tract into the left branch pulmonary artery. (**b**) In the left anterior oblique (LAO) view at 30–55°, a line can be drawn from the posterior aspect of the pigtail catheter to the spine at a 45° angle. Intended TS puncture is halfway along this line with the needle directed to the right (posterior). (**b**) In the right anterior oblique (RAO) view at 40–50°, the intended TS puncture is halfway between the posterior boundary of the atria and a line drawn extending down from the posterior aortic wall, approximately 1–3 cm below the noncoronary cusp

15.4.2 Echocardiography

Nonetheless, distortion of the IAS decreases the efficacy of conventional fluoroscopy in identifying the anatomic landmarks. Echocardiography can offer high-resolution images of important cardiac structures, originally via transthoracic and more recently through transesophageal (TEE) and intracardiac (ICE) echocardiography. *3D TEE* enables even more comprehensive imaging of the heart, using either volumetric or multiplane 2D imaging [4, 5]. 3D imaging of the IAS closely parallels true anatomic inspection and is implicitly understood with the image easily rotated from the RA to LA perspective and intracardiac catheters and devices well visualized. Alternatively, ICE provides 2D and now *3D ICE* imaging with clear definition of all intracardiac catheters, the IAS, septal tenting prior to puncture, and bubble visualization in the LA confirming needle position [6].

15.5 Advanced Imaging and Site-Specific Puncture

With recent technological improvements, the integration of TEE with fluoroscopy in the catheterization laboratory, also known as *echo-fluoro imaging*, provides an alternative to traditional image-guided TS catheterization. The basis of fusion imaging relies on the utilization of live echo data and merging it with live fluoroscopy. Echo-fluoro software (Philips Healthcare, Best, Netherlands) automatically registers the 3D TEE field of view, in reference to the probe face plate, with fluoroscopy. After successful registration, a *TS landmark* can be placed on 2D x-plane and adjusted with confirmation in a 3D view. These landmarks are subsequently overlayed onto fluoroscopy to guide TS puncture (Fig. 15.4).


a
Echo
C-arm
X-Ray
Septum
CRAN 3°
RAO 3°
b
Echo
Septum
C-arm
X-Ray
Septum
CRAN 3°
RAO 3°

15.6 High-Risk Transseptal Anatomy

High-risk TS anatomy can vary and includes abnormal rotation of the cardiac axis; distortion of the IAS due to intra- or extracardiac causes; formation of an IAS aneurysm, abnormal fibrosis, hypertrophy, and/or calcification; and the presence of previously placed IAS closure devices. Recognizing these features is essential and modifying the approach to TS puncture necessary. Abnormal rotation of the cardiac axis can occur in the setting of significant ventricular hypertrophy or hypertrophic cardiomyopathy. Intracardiac causes of IAS distortion include LA and RA dilatation as well as many congenital heart defects. A dilated LA has bulging of the IAS toward the RA, making the FO convex. With TS needle descent, the system is directed either too anterior or too posterior. On the other hand, a dilated RA has bulging of the IAS toward the LA. The FO is concave making it a challenge for the TS system to reach. For extracardiac distortion, severe scoliosis can alter the axis of the IAS and a dilated ascending aorta can cause bulging in the anterosuperior aspect of the IAS (Fig. 15.5a, c, d).

Fig. 15.4 Echo-fluoro imaging. (**a**) Echo-fluoro imaging provides an alternative to traditional image guidance with live echo data merged with fluoroscopy. Echo-fluoro software (Philips Healthcare, Best, Netherlands) automatically registers the 3D TEE field of view, in reference to the probe face plate, with fluoroscopy. After successful registration, a transseptal (TS) landmark (*blue dot*) can be placed on 2D x-plane (*upper frames*) and adjusted with confirmation in a 3D view. These landmarks are subsequently overlayed onto fluoroscopy to guide TS puncture (*right lower panel*). (**b**) Successful site-specific TS puncture performed with sheath/dilator advanced into the left atrium at the site of intended position

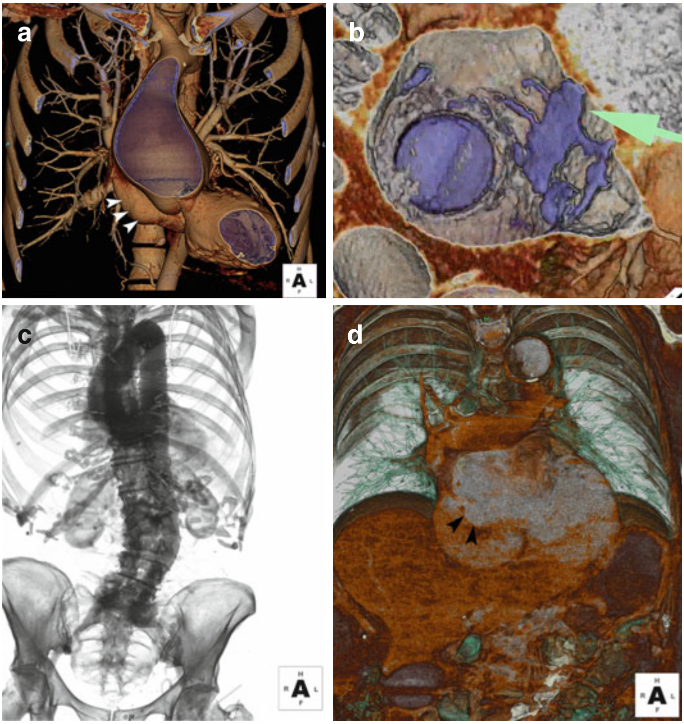


Fig. 15.5 High-risk transseptal anatomy identified by CTA. (**a**) Extracardiac distortion by an ascending aortic aneurysm can cause bulging of the antero-superior aspect of the interatrial septum (IAS) (*white arrowheads*). (**b**) Extensive calcification (*green arrow*) of the IAS can be visualized in a postsurgical patient with limited location for transseptal puncture. (**c**, **d**) Patient with significant scoliosis leading to a more horizontal orientation of the IAS (*black arrowheads*)

Surgically repaired IAS or presence of baffles/conduits can further alter anatomic landmarks with puncture and sheath advancement more difficult in the presence of *endothelialized patch material*. Multiple materials have been utilized including pericardium, Teflon (DuPont, Wilmington DE), Dacron (DuPont), and Gore-Tex (Gore, Flagstaff AZ); however, all can be crossed with minimal risk for residual shunt [7]. Increased thickness or calcification of the FO and local scarring at a prior puncture site can make repeat TS catheterization more challenging with lower success rates than first time punctures [8, 9] (Fig. 15.5b). Lastly, previously placed atrial septal defect (ASD) and patent foramen ovale (PFO) closure devices can equally alter anatomic landmarks with device overlapping varying parts of the septum and most endothelialized making sheath advancement more difficult.

15.7 Alternative Approaches and Advanced Techniques

Difficulties at engaging the FO may be related to many of the anatomical variations described [10]. Bending the standard BK needle to increase (dilated RA) or decrease (dilated LA) curvature and/or bending the patient with the right shoulder down may aid in engagement of the IAS. Alternative equipment such as Brockenbrough needles with additional length of 89 cm or accentuated curve (BK1, 53° angle) may be necessary to reach or engage the FO.

Additional efforts can be made to provide further evidence that the TS needle after puncture is located within the LA and reduce the risk of *LA free wall perforation* [11]. While stabilizing the TS system, the manifold can be removed from the TS needle and an 0.014″ coronary wire inserted and advanced either within the body of the LA or into the left upper pulmonary vein. In addition to verifying location, the wire also minimizes the risk of perforation when the entire system is advanced across the septum.

Radiofrequency (RF) energy can provide an alternative method for TS access over conventional mechanical energy [12, 13].

This can be achieved by using a dedicated RF TS system (Baylis Medical, Montreal, Canada) or direct application of RF to the end of a standard TS needle. The addition of RF cautery decreases the need for significant force applied to the septum for puncture, potentially improving the accuracy and risk of sheath/dilator inappropriate movement.

Finally, increasing numbers of patients presenting for TS cardiac catheterization have undergone previous percutaneous ASD or PFO closure [14–16]. Areas of native septum not covered by the closure device and suitable for TS puncture can be considered. If not available, direct puncture through the device can be performed. Needle puncture of the device can be achieved via standard technique or with the use of RF energy. Once the needle has crossed the device, confirmed by imaging, the dilator is advanced into the LA. The TS needle is subsequently removed and a stiff guidewire then placed into the LA or left pulmonary vein. The tract is further enlarged using either a dilator or small septostomy balloon prior to advancement of the required TS sheath. Caution is necessary in cases where *ASD rims* were less than 5 mm or where inadequately supported large devices or very small devices are present. Traditionally, 6 months should have elapsed prior to attempting this technique to allow for endothelialization and securing of the device. At earlier time points, consideration for device retrieval can be considered.

15.8 Knowing the Contraindications

Despite the many potential indications, it is equally important to understand the contraindications to this procedure. The presence of *atrial thrombus or mass*, either in the right or left atrium, is an absolute contraindication. Organized thrombus specifically localized within the left atrial appendage is a relative contraindication and should only be performed by experienced operators with the ability to utilize advanced imaging modalities to reliably avoid the LAA with catheters and wires. The presence of smoke is not a contraindication, and coagulopathy with an INR of >2.5 and/or a platelet count of <50,000 cell/dL is not recommended without reversal. In addition, a disruption of the normal inferior vena caval (IVC) flow excludes a traditional transfemoral venous approach to TS puncture.

15.9 Complications

TS puncture, on the whole, is a reasonably safe procedure with complication rates around 1 %. Complications that can occur include the following: cardiac perforation, causing hemopericardium ± *pericardial tamponade* due to perforation of the RA or LA walls, LAA, or coronary sinus; *aortic wall perforation*; IVC perforation and retroperitoneal hematoma; cardiac arrhythmias such as atrial tachyarrhythmias and heart block; *systemic embolization* either from air, thrombus, cholesterol, or calcium; and death. Contemporary experience has revealed rates of tamponade ranging from 1 to 3 %, systemic embolization less than 1 %, and mortality of 0.1 % [17–19]. The highest risk typically occurs either during the puncture or during advancement of the sheath into the LA. The factors that influence complication rates include the type of procedure, whether it is diagnostic or interventional, levels of anticoagulation, sheath size, left atrial pressure, presence and compliance of the pericardium, the use of imaging for TS guidance, and, most importantly, operator learning curve.

15.10 Conclusion

Recent expansion of left-sided diagnostic and interventional procedures has led to a resurgence of TS cardiac catheterizations. Understanding the indications/contraindications, IAS anatomy, the technical aspects of TS puncture and its associated complications are paramount. Alternative techniques for the difficult, high-risk patient should be recognized and employed. In addition, the use of multimodality imaging is essential for accurate TS localization and procedural safety. More advanced imaging such as echo-fluoro imaging may play a greater role as site-specific TS puncture is required. Overall, TS access is a valuable procedure that can be successfully performed with minimal risk to the patient.

References

1. Ross J Jr, Braunwald E, Morrow AG (1959) Transseptal left atrial puncture; new technique for the measurement of left atrial pressure in man. Am J Cardiol 3(5):653–655
2. Tzeis S, Andrikopoulos G, Deisenhofer I, Ho SY, Theodorakis G (2010) Transseptal catheterization: considerations and caveats. Pacing Clin Electrophysiol 33(2):231–242
3. Rocha P, Berland J, Rigaud M, Fernandez F, Bourdarias JP, Letac B (1991) Fluoroscopic guidance in transseptal catheterization for percutaneous mitral balloon valvotomy. Cathet Cardiovasc Diagn 23(3): 172–176
4. Eng MH, Salcedo EE, Kim M, Quaife RA, Carroll JD (2013) Implementation of real-time three-dimensional transesophageal echocardiography for mitral balloon valvuloplasty. Catheter Cardiovasc Interv 82:994–998
5. Faletra FF, Nucifora G, Ho SY (2011) Imaging the atrial septum using real-time three-dimensional transesophageal echocardiography: technical tips, normal anatomy, and its role in transseptal puncture. J Am Soc Echocardiogr 24(6):593–599
6. Mitchel JF, Gillam LD, Sanzobrino BW, Hirst JA, McKay RG (1995) Intracardiac ultrasound imaging during transseptal catheterization. Chest 108(1):104–108
7. El-Said HG, Ing FF, Grifka RG et al (2000) 18-year experience with transseptal procedures through baffles, conduits, and other intra-atrial patches. Catheter Cardiovasc Interv 50(4):434–439; discussion 440

8. Tomlinson DR, Sabharwal N, Bashir Y, Betts TR (2008) Interatrial septum thickness and difficulty with transseptal puncture during redo catheter ablation of atrial fibrillation. Pacing Clin Electrophysiol 31(12):1606–1611
9. Marcus GM, Ren X, Tseng ZH et al (2007) Repeat transseptal catheterization after ablation for atrial fibrillation. J Cardiovasc Electrophysiol 18(1):55–59
10. Sy RW, Klein GJ, Leong-Sit P et al (2011) Troubleshooting difficult transseptal catheterization. J Cardiovasc Electrophysiol 22(6):723–727
11. Hildick-Smith D, McCready J, de Giovanni J (2007) Transseptal puncture: use of an angioplasty guidewire for enhanced safety. Catheter Cardiovasc Interv 69(4):519–521
12. Sherman W, Lee P, Hartley A, Love B (2005) Transatrial septal catheterization using a new radiofrequency probe. Catheter Cardiovasc Interv 66(1):14–17
13. McWilliams MJ, Tchou P (2009) The use of a standard radiofrequency energy delivery system to facilitate transseptal puncture. J Cardiovasc Electrophysiol 20(2):238–240
14. Santangeli P, Di Biase L, Burkhardt JD et al (2011) Transseptal access and atrial fibrillation ablation guided by intracardiac echocardiography in patients with atrial septal closure devices. Heart Rhythm 8(11):1669–1675
15. Katritsis DG (2011) Transseptal puncture through atrial septal closure devices. Heart Rhythm 8(11):1676–1677
16. Chen K, Sang C, Dong J, Ma C (2012) Transseptal puncture through Amplatzer septal occluder device for catheter ablation of atrial fibrillation: use of balloon dilatation technique. J Cardiovasc Electrophysiol 23(10): 1139–1141
17. Roelke M, Smith AJ, Palacios IF (1994) The technique and safety of transseptal left heart catheterization: the Massachusetts General Hospital experience with 1,279 procedures. Cathet Cardiovasc Diagn 32(4):332–339
18. B-Lundqvist C, Olsson SB, Varnauskas E (1986) Transseptal left heart catheterization: a review of 278 studies. Clin Cardiol 9(1):21–26
19. Clugston R, Lau FY, Ruiz C (1992) Transseptal catheterization update 1992. Cathet Cardiovasc Diagn 26(4):266–274