

Transseptal Puncture: A Step-by-Step Procedural Guide

Knowledge of interatrial septum anatomy, appropriate equipment, and proper technique are key to successful transseptal puncture.

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The transseptal puncture (TP) technique was introduced into clinical practice during the late 1950s by Ross et al as a diagnostic tool to properly select patients for cardiac valve surgery.^{1,2} Over the years, its use for diagnostic purposes has declined, but a number of new interventional procedures utilizing TP have been developed. Currently, the most common indications are left heart electrophysiology ablations, percutaneous mitral valve repair/implantation, patent foramen ovale closure, left atrial appendage occlusion, paraprosthesis valve leak repair, and left ventricular assist device positioning.

The increasing number of interventional procedures as well as the use of large-bore sheaths and complex devices have led to improvements in technique and equipment. However, TP is still technically challenging, and some complications may occur. Consequently, special training is required, and only expert operators should perform TP. Because anatomic landmarks are not visible under fluoroscopy, the use of echocardiography has become essential to increase safety and allow for more precise determination of the crossing-point location within the atrial septum.

To achieve a successful procedure and avoid complications, a deep knowledge of interatrial septum (IS) anatomy, available equipment, correct imaging guidance, and procedural steps is needed. The aim of this article is to provide a step-by-step guide for the TP procedure and to describe available novel transseptal technologies.

EQUIPMENT

The initial needle used by Ross had a curved distal end to allow controlled movements of the tip and an arrow-shaped proximal handle to define needle orientation. Although design features have remained the same over the

years, Brockenbrough modified the Ross needle by reducing the caliber of the distal 1.5 cm of the needle from 18 to 21 gauge.^{3,4}

The Brockenbrough needle is made of stainless steel and has a stylet inside the lumen to prevent friction while advancing it into the sheath. The standard BRK needle (Abbott Vascular), a type of Brockenbrough needle, has a 19° angle between the distal curved part and the needle shaft, whereas the BRK 1 (Abbott Vascular) is characterized by a 53° angle curvature. Pediatric needles are also available with different lengths and curves.

Several sheaths with a dilator protruding beyond the sheath tip can be used with Brockenbrough needles. The most common sheaths are represented by a Mullins sheath or a Swartz SL transseptal sheath (Abbott Vascular), which are available with different bores (8–12 F are used most)

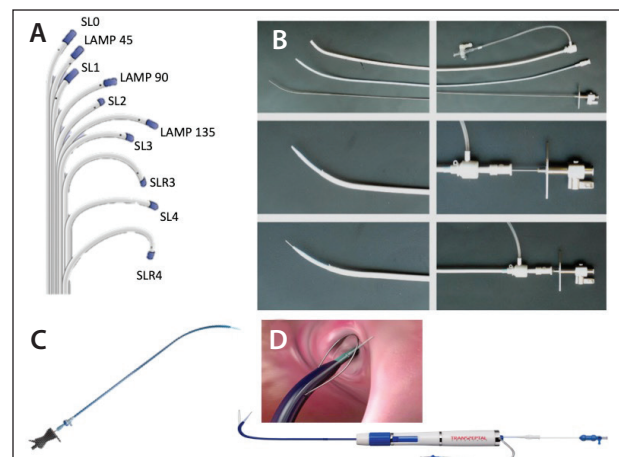


Figure 1. Swartz SL transseptal sheaths (A); Abbott transseptal kit (B); NRG RF transseptal needle (C); TSP Crosser kit (D).

and different curvature versions according to atrial anatomic features. Several manufacturers now produce transseptal kits, although they have only slight variations in design (Figure 1).

FOSSA OVALIS AND ATRIAL SEPTUM ANATOMY

Before describing the TP procedure, it is of utmost importance to become familiar with IS anatomy. The anatomic IS is the entire area interposed between the two atria and should be distinguished from the “true” IS, which is only the area that can be crossed without going in the extracardiac space and accounts for only approximately 20% of the total septal area.⁵

The fossa ovalis is part of the true IS and is located in the lower posterior part of the IS. It is either an oval or, less frequently, a round-shaped depression that is primarily composed of thin fibrous tissue. The fossa ovalis can be schematically divided into four parts (Figure 2A): (1) superior-anterior, (2) inferior-anterior, (3) superior-posterior, and (4) inferior-posterior.

Its shape may significantly vary according to atrial size, pressure, and tissue redundancy. The three-dimensional reconstruction in Figure 2B and 2C shows different puncture sites within the right and left sides of the fossa ovalis and their relationship within the mitral valve.

ECHOCARDIOGRAPHIC PREPROCEDURAL ASSESSMENT

Periprocedural transesophageal echocardiography (TEE) is recommended in all patients undergoing TP because it provides useful insights into the IS anatomy (eg, patent foramen ovale or atrial septal defects). It also allows for detection of left atrial thrombus or an atrial tumor, which represent contraindications to TP.

STEP-BY-STEP TRANSSEPTAL PUNCTURE PROCEDURE



To watch an accompanying video demonstrating transseptal puncture, please view this article on our website at www.citoday.com.

Step 1: Femoral Puncture

Both groins should be prepared because invasive arterial monitoring might be needed should any complication occur. However, a right-side venous femoral puncture is usually preferred for the TP procedure due to the more

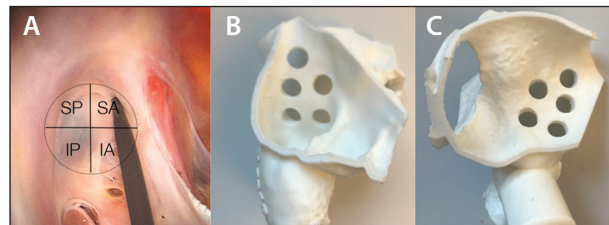


Figure 2. Fossa ovalis anatomy from the RA view and its schematic division into four parts (A). Three-dimensional models showing the IS from the right side (B) and the left side (C). IA, inferior-anterior; IP, inferior-posterior; SA, superior-anterior; SP, superior-posterior.

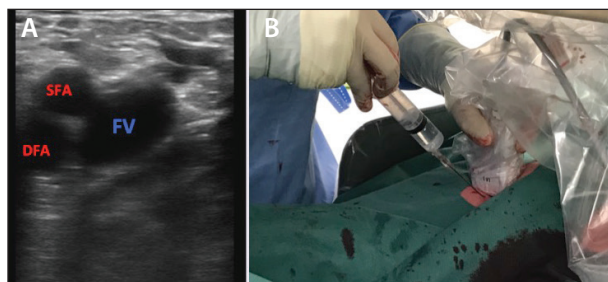


Figure 3. Echo-guided femoral puncture in the SAX view (A) and operative field setting (B). DFA, deep femoral artery; FV, femoral vein; SFA, superficial femoral artery.

linear trajectory to the right atrium (RA). In case of unfavorable right venous axis anatomy, the left side can be used; however, catheter trackability may be more difficult. Access from the left side also often requires a more curved needle to reach the fossa.

To achieve a safe femoral puncture, fluoroscopic and/or ultrasound guidance is strongly suggested. A low puncture is advisable because the femoral vein does not bifurcate and it is a reasonable size until a few centimeters from the inguinal ligament. In this way, the risk of retroperitoneal bleeding is reduced. Echo guidance with a linear probe allows the operator to follow the needle and change its direction while reaching the vein to avoid femoral artery puncture (Figure 3). The fluoroscopic landmark (anteroposterior [AP] projection) is represented by the femoral head: the puncture should be medial to it and below its equator.

An alternative option is to palpate the femoral pulse and puncture 4 cm below the inguinal ligament, medial to the femoral pulse, and with a 45° inclination starting medial and shifting lateral.

Step 2: Sheath Introduction

Under fluoroscopic guidance (AP projection), a 0.032-inch J-tip guidewire is advanced. The needle is removed, and using the scalpel, the skin is prepared for large-bore introducer insertion. A sheath introducer (usu-

ally 8–12 F) is inserted and then flushed. Preclosure with a closure device (Perclose ProGlide, Abbott Vascular) should be considered.

During this phase, it is advisable to administer 1,000 to 2,000 U of heparin to avoid device thrombosis because TP may be tricky and require additional time. Some operators use an 18-F sheath at this time, although the use of large-bore sheaths in the venous system is associated with clotting within the sheath and a consequent risk of embolization.

Step 3: Mullins Sheath Insertion

At this point, the 0.032-inch J-tip guidewire can be advanced under fluoroscopic guidance (AP projection) from the femoral vein to the superior vena cava (SVC). The wire should be positioned anterior to pacemaker electrodes when present (in the left anterior oblique projection, the wire should appear on the right side of the screen compared to the electrodes). TEE in the bicaval view may be used to confirm that the guidewire has reached the SVC position.

Keeping the same fluoroscopic and TEE projections, the transseptal sheath and dilator can be advanced over the guidewire to the SVC. Once the sheath has reached 3 to 4 cm superior to the cavoatrial junction, the wire is removed, keeping the tip of the sheath facing left on the AP view.

Step 4: Brockenbrough Needle Insertion

When inserting the Brockenbrough needle inside the Mullins sheath, the needle should be advanced gently, allowing the arrow to rotate freely to negotiate the tortuosity of the anatomy. The needle is advanced under fluoroscopic guidance (AP projection) until it reaches the Mullins sheath tip. To avoid perforations, it is essential in this step to not push the needle over the tip of the sheath. The needle is advanced with the stylet inserted until it reaches 4 cm from the tip. The stylet prevents the needle tip from scraping the inner lumen of the Mullins sheath. The stylet can then be removed and the luer lock of the needle can be connected to the pressure line.

Step 5: Pullback

In this step, the needle and the sheath are held in the fingers to prevent inadvertent advancement of the needle, and the position of the Brockenbrough needle arrow is at 5 or 6 o'clock, according to different procedures (Figure 4). To target a more posterior puncture location, the arrow should be kept at the 6 o'clock position. The needle and the sheath are pulled back caudally until they are visualized in the inferior portion of the SVC. Tenting should be monitored by echocardiography (bicaval view)

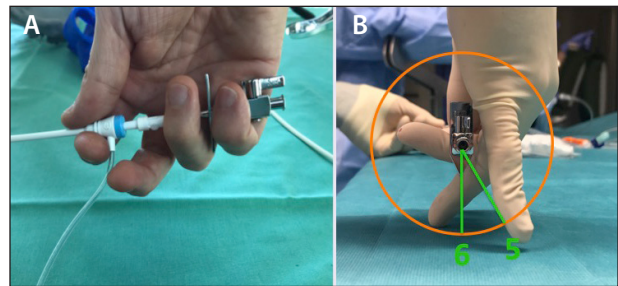


Figure 4. Correct handling (A) and orientation (B) of the Mullins sheath and Brockenbrough needle during the pull-back maneuvers.

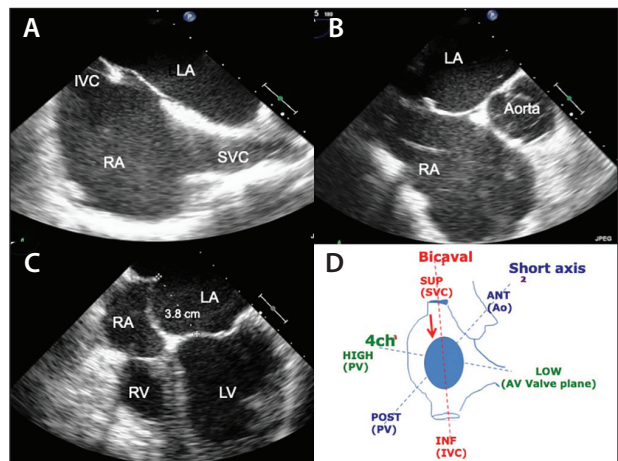


Figure 5. TEE bicaval view (A), SAX at the base view (B), and four-chamber view (C) during the pullback phase of TP. Schematic view of the three main TEE projections used during TP in relation to the anatomic structures they show (D). 4ch, four chamber; ANT, anterior; Ao, aorta; AV valve, atrioventricular valve; INF, inferior; IVC, inferior vena cava; LV, left ventricle; PV, pulmonary vein; RV, right ventricle; SUP, superior.

in the lower part of the SVC before the needle falls into the fossa. Usually, as the needle tents the superior rim of the fossa, supraventricular extrasystolic beats are generated. During this phase, the TEE operator should avoid moving the image from the membranous portion of the septum, and the interventionalist should try to move in the direction of the image.

Fluoroscopy (AP projection) serves two purposes in this step: (1) to monitor the position (AP rotation) of the needle tip until it falls into the fossa and (2) to avoid pulling back too much toward the inferior vena cava.

Next, under TEE monitoring (bicaval view), the needle and sheath are pulled back until they fall into the fossa and tenting is obtained (Figure 5A). At this point, TEE moves to the short axis (SAX) at the base view and position of the tenting is checked; it should be posterior in most patients undergoing mitral interventions (Figure 5B).

Once the transseptal system falls into position in the fossa, to change positions, the operator has to move in two directions at the same time to prevent pivoting of the needle. An isolated clockwise rotation will result in rotation of the sheath without a change in the contact point. To move posteriorly, the operator has to combine rotations with slight pulling of the catheter to allow mobilization of the tip—if the tenting is too anterior, a clockwise torque on the needle with an associated slight pullback movement is done under fluoroscopic guidance to move posteriorly; if the tenting is too posterior, a counterclockwise rotation with concomitant pullback movement should be applied.

In the case of MitraClip (Abbott Vascular) procedures, TEE should now switch to the four-chamber view and measure the height of the puncture (the distance between the tenting and the mitral annulus) (Figure 5C). In patients with degenerative mitral regurgitation, the ideal height is > 4 cm, whereas in functional mitral regurgitation, a 3-cm distance is acceptable. Given the flexibility of the membranous septum, the height of the puncture may be reduced during steering of the devices; therefore, in the presence of a floppy septum, higher punctures may be recommended.

Ideal locations of the puncture depend on the specific devices used and the patient characteristics. A MitraClip procedure is usually performed with posterior punctures in the segments superior-posterior and inferior-posterior. A Cardioband (Edwards Lifesciences) procedure is performed with more anterior punctures (superior-anterior and inferior-anterior) and left atrial appendage closure is usually performed through an inferior puncture (usually inferior-posterior). Main TEE projections and related visible anatomic structures are shown in Figure 5D.

Step 6: Transseptal Puncture

TEE should move to the SAX view, and fluoroscopy should be in the AP projection. In this step, the needle is advanced while keeping the transseptal sheath in place. Only slow movements should be done in this phase to prevent the system from slipping too anterior to the SVC (toward the aorta) or too posterior to the SVC (to the Waterston groove).

To prevent this risk, as an alternative to conventional techniques, the puncture can be assisted by the use of a diathermy surgical system⁶ or radiofrequency [RF] transseptal systems (NRG RF transseptal kit, Baylis Medical Company, Inc.),⁷ enhancing safety and precision to the puncture.

Puncture of the fossa is usually followed by release of the tenting, visible on TEE. For additional safety, left atrial pressure should be confirmed before advancing the transseptal sheath. In the absence of pressure tracing or in case of aortic pressure, the sheath should not be advanced. After

puncture, additional heparin to reach full heparinization (100 U/kg) should be administered, aiming for an activated clotting time of 250 to 300 seconds for most procedures.

Step 7: Sheath Advancement Into the Left Atrium

If a left atrial pressure curve is present, the transseptal sheath can be advanced. Both the transseptal sheath and the needle should be advanced under TEE guidance until 1 to 2 cm is in the left atrium (LA). Then, holding the needle, the sheath is advanced over the needle. Finally, the needle and the dilator are kept steady and the sheath is advanced over the dilator. When the tip of the sheath is close to the edge of the heart shadow, the needle (and eventually the dilator) can be slowly retrieved. When using Mullins sheaths, it is advisable not to retrieve the dilator completely to avoid kinking of the sheath. The transseptal sheath is deaired and a 0.032-inch guidewire is advanced toward the left superior pulmonary vein.

Step 8: Advancement of the Transseptal Sheath Toward the Left Superior Pulmonary Vein

In this step, a TEE four-chamber view is needed to confirm that the guidewire is not in the appendage, and fluoroscopy (AP projection) may help track the wire toward the pulmonary veins. During this phase, clockwise rotation of the sheath while advancing the 0.032-inch guidewire is useful to negotiate the pulmonary veins.

Step 9: Amplatz Super Stiff Guidewire Into the Left Superior Pulmonary Vein

While keeping the system in the pulmonary vein, an Amplatz Super Stiff guidewire (Boston Scientific Corporation) is advanced into the pulmonary vein as a buddy wire under fluoroscopic guidance. The transseptal sheath and the 0.032-inch guidewire can then be removed. If left atrial pressure monitoring is required (eg, for continuous reading of the left atrial pressure during a MitraClip procedure), a 4- to 5-F pigtail catheter can be advanced over the 0.032-inch buddy guidewire through the same vein puncture.

Step 10: Advancement of the Guiding Catheter (MitraClip Procedure)

Fluoroscopic AP and TEE SAX views are the key projections for this last step. After proper groin dilatation, the guiding catheter is advanced over the wire. Holding a wet sponge with the left hand on the groin to activate the hydrophilic coating and a dry sponge in the right hand to enhance catheter grip, the guiding catheter is advanced into the femoral vein. It is then slowly advanced further until the guiding catheter enters the LA. Then, the tip of the dilator is retracted, keeping the wire in place so as not

to lose the transseptal position. The tip of the guiding catheter must be inside the LA, 2 cm from the septum. Finally, the wire is removed and the system is deaired.

NEW TECHNOLOGIES

Due to the huge number of procedures necessitating TP and the need for precise and safe puncture, new devices and technologies have been developed in recent years. The TSP Crosser (Transseptal Solutions, Ltd.) represents an all-in-one system for TP and steerable left atrial catheter navigation. It is made of two main components: (1) a stabilizing loop wire that locates and defines the fossa ovalis boundaries and (2) the crosser, which is a steerable system that allows pre-puncture steering and adaptation to the patient anatomy, enhanced control during navigation around the fossa ovalis, and increased stability during puncture. Once TP is performed, the steerable catheter is used for intra-atrial navigation and guiding catheters and wires toward therapy targets (eg, perivalvular leak closure).

Alongside this, technology based on RF has been developed to increase precision, allow safe puncture, and use in case of challenging septa: the NRG RF transseptal kit.⁸ The Brockenbrough needle is substituted for the NRG transseptal needle (Baylis Medical Company, Inc.), which is introduced into the dilator-sheath assembly (TorFlex transseptal guiding sheath, Baylis Medical Company, Inc.). This RF needle delivers 5- to 10-W energy for 2 to 5 seconds and can perforate the atrial septum after 1 to 4 pulses.^{8,9} This technology may have an advantage in thick, scarred, calcified, or patched atrial septa, where excess force could result in unsuccessful puncture or perforation of the LA free wall. The buildup of momentum by the needle and sheath in this situation can lead to an overshoot phenomenon, in which the superior or contralateral wall of the LA is inadvertently punctured once the system passes through the septum.

Alternatively, the SafeSept needle-free transseptal guidewire (Pressure Products Medical Supplies, Inc.) has been recently tested.¹⁰ The SafeSept guidewire is a 180-cm-long, 0.0315-inch-diameter nitinol guidewire that is designed for safe, easy transseptal puncture. Its sharp tip easily perforates and crosses the fossa. It can be used in conjunction with a transseptal dilator and introducer to create the primary puncture in the IS without the need for a transseptal needle. The tip of the guidewire assumes a J-shape when unsupported by the dilator and sheath, making it incapable of further tissue penetration.

CONCLUSION

Although the technique and equipment have mostly remained the same since the first description in late 1950s, the growing number of indications for TP and the need for precise and safe puncture have brought refreshing new

ideas and devices. The most important adjunctive feature has been intraprocedural echocardiography (TEE or intracardiac echo) because it adds precision and safety and also allows less experienced operators to perform TP. The combination of fluoroscopic and transesophageal echocardiographic images (eg, EchoNavigator, Philips) may further facilitate the procedure.¹¹ Of course, procedures that require TP will increase in both frequency and complexity (eg, mitral valve implantation); for this reason, further improvement to techniques and devices will likely be required. ■

1. Ross J Jr, Braunwald E, Morrow AG. Transseptal left atrial puncture: new technique for the measurement of left atrial pressure in man. *Am J Cardiol*. 1959;3:653-655.
2. Ross J Jr, Braunwald E, Morrow AG. Transseptal left heart catheterization: a new diagnostic method. *Prog Cardiovasc Dis*. 1960;2:315-318.
3. Brockenbrough EC, Braunwald E, Ross J Jr. Transseptal left heart catheterization: a review of 450 studies and description of an improved technic. *Circulation*. 1962;25:15-21.
4. Brockenbrough EC, Braunwald E. A new technic for left ventricular angiography and transseptal left heart catheterization. *Am J Cardiol*. 1960;6:1062-1064.
5. Klimmek-Piotrowska W, Holda MK, Koziej M, et al. Anatomy of the true interatrial septum for transseptal access to the left atrium. *Ann Anat*. 2016;205:60-64.
6. Maisano F, La Canna G, Latib A, et al. Transseptal access for MitraClip® procedures using surgical diathermy under echocardiographic guidance. *EuroIntervention*. 2012;8:579-586.
7. Sakata Y, Feldman T. Transcatheter creation of atrial septal perforation using a radiofrequency transseptal system: novel approach as an alternative to transseptal needle puncture. *Catheter Cardiovasc Interv*. 2005;64:327-332.
8. Sherman W, Lee P, Hartley A, Love B. Transatrial septal catheterization using a new radiofrequency probe. *Catheter Cardiovasc Interv*. 2005;66:14-17.
9. Smalley MP, Shah DP, Weisberg J, et al. Initial experience using a radiofrequency powered transseptal needle. *J Cardiovasc Electrophysiol*. 2010;21:423-427.
10. Honarbakhsh S, O'Brien B, Schilling RJ. A simplified trans-septal puncture technique using a needle free approach for cryoablation of atrial fibrillation. *J Atr Fibrillation*. 2017;10:1628.
11. Faletra FF, Bisco L, Pedrazzini G, et al. Echocardiographic-fluoroscopic fusion imaging in transseptal puncture: a new technology for an old procedure. *J Am Soc Echocardiogr*. 2017;30:886-895.

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