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Transseptal Access for the Electrophysiologist: Anatomic Considerations to Enhance Safety and Efficacy

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ABSTRACT. Safe and reproducibly effective transseptal puncture and access to the left atrium and ventricle is now a prerequisite for the practicing invasive electrophysiologist. In this review, we examine, in turn, the relative regional anatomy that necessarily forms the backdrop for the expected safety with this procedure. We then review the tools and options available for transseptal puncture and emphasize the importance of meticulous attention to detail with regard to sheath management and anticoagulation. Finally, we briefly review less common situations where transseptal access is required and present an overall approach based on the above considerations in approaching this important technique in these situations.

KEYWORDS. ablation, anticoagulation, complications, thrombus, transseptal puncture.

Introduction

Over the last 15 years, cardiac electrophysiologists have become the most proficient in performing transseptal puncture and are by far the most common cardiac subspecialists called upon to effectively and safely puncture the interatrial septum. Access to the left atrium via the transseptal approach was originally developed by Drs. Andrew Morrow, Eugene Braunwald, and John Ross, Jr. in the 1950s, primarily for assessing intracardiac hemodynamics.1–4 Brockenbrough refined the procedure with several critical modifications of the transseptal needle.5 As time evolved, the procedure was required less for assessing hemodynamics but rather as a means to gain access to the left atrium and left ventricle for therapeutic procedures such as mitral valvuloplasty, placement of assist devices, and radiofrequency ablation.6,7 At first, electrophysiologists relied on colleagues who had gained proficiency from the hemodynamic assessment era when the technique was infrequently needed (failed retrograde approach for left-sided accessory pathway). With atrial fibrillation ablation, all invasive electrophysiologists necessarily required the skill or have become proficient in entering the left atrium. A thorough understanding of the regional anatomy is critical to safely perform transseptal puncture and anticipate particularly difficult situations in which complications may arise.

In this review, the pertinent developmental and regional anatomy of the interatrial septum relevant to fully appreciating the utility of fluoroscopy and echocardiography in executing safe transseptal puncture is explained.8,9 Where relevant, specifically practical points for the electrophysiologists are highlighted and outlined.

Normal anatomy and development of the interatrial septum

An appreciation of the anatomy of the interatrial septum and fossa ovalis (FO) is essential to safe and efficacious transseptal puncture (Figure 1). The true atrial septum represents a relatively small area within what was previously referred to as the atrial septum.

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The primary septum first develops as a muscular ridge on the atrial roof and grows into the cavity with a mesenchymal cap. The initially singular pulmonary vein enters from the dorsal aspect of the primary atrium, and it is the rightward mesenchymal ridge next to it that becomes the vestibular spine. As the spine grows inward it fuses with the mesenchymal cap of the primary septum and the atrioventricular endocardial cushion, obliterating the primary atrial foramen. Muscularization of this spine then produces the anteroinferior border of the FO, with the primary septum forming the fibrous tissue of the FO itself.

Of necessity, the upper part of the primary septum has broken down to form the secondary foramen prior to obliteration of the primary foramen. The roof of the atrium then begins a process of infolding, resulting in an inner layer of adipose tissue between the myocardial layers that is often referred to as the septum secundum; however, this is not a true septum as posterior to the FO a puncture will be into the adipose tissue between the two atria and therefore extracardiac. This infolding then forms a site for the flap-valve that was the primary septum to rest, which fuses in two-thirds to three-quarters of the population. As a result of this process, we can define the true interatrial septum as that area that directly connects the two atria and the ridge below, which is the muscularized vestibular spine.

The inferior border of the FO is marked by the inferior vena cava (IVC) with the coronary sinus (CS) at the anteroinferior border, having developed from the left sinus horn. The anterior border is marked by the septal portion of the tricuspid annulus.

Superior to the FO is the superior vena cava (SVC) with the non-coronary cusp of the aorta forming the anterosuperior component. The ridge around the superoposterior fossa is the limbus, which represents the leading edge of the infolding of the atrial roof that also forms the posterior border of the FO.

**Practical points for the electrophysiologist**
- Because of the way the right atrium develops, the FO is found in a straight line joining the anterior third of the SVC to the middle third of the IVC.

### Anatomical variants

**Patent foramen ovale**

A patent foramen ovale (PFO) is present by echocardiographic evaluation or by probe in approximately one-quarter of the population. It is located in the anterosuperior border of the FO and may be either direct or a long tunnel (Figure 2). Relative to the normal site of transseptal puncture, it is both superiorly and anteriorly directed and can lead to difficulty in accessing the more posteroinferior pulmonary veins. It was shown in one series that use of a PFO was associated with more radiofrequency applications to isolate the veins; however, total procedure and fluoroscopy times were not affected. Of note, in this study, a transseptal puncture was still performed to pass a circular mapping catheter, and the ablation catheter was passed via the PFO where possible and did not look at difficulty using a PFO to pass both mapping and ablation catheters (analogous to a single puncture technique – see below).

**Practical points for the electrophysiologist**
- Even if a PFO is present, transseptal puncture may still be preferred. This is because the PFO tends to be superior and superiorly directed, sometimes creating difficulty for accessing the inferior pulmonary veins and the posteroinferior mitral annulus.

### Left atrial and aortic root dilatation

Dilatation of the left atrium (LA), whether related to hypertension or valvular disease, will tend to direct the FO more posteriorly. It has also been shown that a more posterior location is common with increasing age, possibly through the same mechanism. Dilatation of the aortic root will tend to direct the FO in a more posterior direction.

### Patches and baffles

Transseptal puncture has been documented in the presence of both artificial and pericardial patch repairs as well as at the inferoposterior border of atrial septal defect closure devices. The use of intracardiac echocardiography (ICE) for these cases has not been systematically studied but anecdotally has been found to be beneficial at our institution.
Dextrocardia represents a significant challenge to transseptal puncture; however, cases have been reported of successful access to the right atrium (RA) using a mirror image technique (with the needle guided to the 7 o’clock instead of the 5 o’clock position) and of puncture of a baffle in a patient with concomitant dextrocardia for atrial tachycardia with successful outcomes.12

Relevant anatomy to procedural risks

Posterior

As mentioned previously, the posterior component of the FO is bordered by the atrial infolding, comprising two muscular layers, and an inner adipose layer. Puncture through this area would lead to a pericardial location. In addition, with sufficient forward motion, the needle may pass between the two layers and into the LA. This could be mistaken as a successful puncture and the sheath advanced. This should be suspected if cardiac tamponade develops as the transseptal sheath is withdrawn.

Anterior

The most feared complication of transseptal puncture is penetration of the needle into the aortic root (Figure 3). Puncture into the non-coronary cusp can be recognized by injection of contrast and changes in the pressure waveform. If this complication is not recognized and the sheath advanced into the aortic root, then surgical repair is mandated. Removal of the sheath should only be performed under direct surgical guidance and not prior to operation, as tamponade is likely to result.

The placement of a pigtail catheter into the aortic root via the femoral artery is used by some operators. This will lead to the correct puncture site being inferior in the left anterior oblique (LAO) view and posterior and inferior in the right anterior oblique (RAO) view.

If the puncture is made below the level of the aortic root, other structures at risk include the bundle of His, which is located at the level of the membranous septum at a point marked by the junction of the right and non-coronary cusps of the aortic valve. For this reason, some operators place a His bundle catheter to mark both the His bundle and by proxy, the aortic root. Electrophysiology catheters can be used as landmarks.13

Inferior

The most important structure to consider inferior to the FO is the coronary sinus (CS). One study has shown that the usual puncture site is approximately 10–14 mm from the ostium of the CS as marked by a catheter introduced...
from above and dependent on age. If a CS catheter is present, the puncture site should be superior and posterior in the RAO view or superior in the LAO view.

**Practical points for the electrophysiologist**

- In the RAO view, maintaining transseptal needle position in the same axis connecting the anterior third of the SVC and middle third of the IVC avoids most complications.
- Anterior to this plane, lie the ascending aorta, conduction tissue, and the coronary sinus.
- Posterior to this plane risks direct puncture into the pulmonary veins or posterior wall of the right and left atria.

**Essential components of the transseptal procedure**

**Equipment preparation**

Equipment preparation begins with the sheath and needle setup. The use of a manifold will reduce the chance of inadvertent introduction of air while changing syringes and allow easy measurement of pressure during the puncture. All sheaths should be flushed with saline initially and care taken to establish a fluid–fluid interface when connecting equipment. If contrast is used at any stage, especially through the Brockenbrough needle, it is important to remember that due to differences in viscosity of the fluid and the diameter of the needle, further pressure measurements may be altered unless the needle is flushed with saline. Care should also be taken to wipe any wire during sheath exchange to prevent inadvertent thrombus introduction.

At our institution, we use a CS catheter placed from the right internal jugular vein via a 7 French sheath, and two 8 French sheaths placed in the right femoral vein. The right femoral vein is a more direct and less tortuous route for transseptal puncture. For the puncture itself, we prefer the Brockenbrough family of needles (BRK/BRK1/BRKXS) and an SL1 sheath, which is then commonly exchanged later for an Agilis sheath.

During the entire procedure, the sheaths are continually flushed with heparinized saline. After careful preparation of the equipment, proper technique during the procedure is important to avoid complications. As embolization is a major potential complication, rigorous attention should be focused on proper technique during the procedure to avoid air and catheter-associated thrombus embolization.

**Anticoagulation**

There exist slight differences in timing of anticoagulation between groups. Our preference is for early heparinization with the first transseptal puncture. This is due to evidence of early thrombus formation on ICE studies that can occur in the RA and potentially be transferred to the LA. The use of ICE to guide the puncture results in this being a safe and efficacious approach.

**Sheath positioning**

Via the femoral venous sheath, a 0.032-inch J-wire is introduced up the IVC, through the RA, and into the SVC. The 8 French groin sheath is then exchanged for an 8.5 French SL1 sheath (when using the Navistar catheter, whereas a 7.5 French may be used with the NavX system), which is advanced into the SVC to the approximate level of the carina. We prefer to retract the dilator in preparation for movement in the SVC as it is more traumatic than the sheath itself.

**Needle puncture**

Initial preparation for the BRK or BRK1 needle by some operators includes manually altering the curvature of the needle. The needle is connected to the manifold with a fluid–fluid interface and opened to pressure monitoring. Once this has been done, the 0.032 wire is removed and the BRK is advanced through the sheath/dilator assembly, again with an initial fluid–fluid interface, with the needle guide angled at approximately 5 o’clock for a
normal heart. The needle is advanced until the guide is approximately 1.5 inches from the base of the dilator.

Once this is in place, the entire assembly is withdrawn down the SVC. For the process, the operator is aligned at 90° to the patient with the left hand holding the sheath and the right hand on the dilator/needle assembly. As the assembly is withdrawn, ensuring that everything is kept in a straight line, the operator should observe for two “jumps,” the first of which is the point where the sheath passes over the aortic knob and SVC–RA junction into the RA. The dilator is kept steady as the sheath is withdrawn over it. The second jump is the passage of the dilator inferiorly over the limbus into the FO. The dilator is advanced slightly to catch in the FO, and its position is confirmed with ICE. If the assembly passes over the FO instead of catching, then the needle is replaced with the 0.032 wire, and the process is repeated with a slight anterior or posterior angulation adjustment.

Fluoroscopic views of the position of the catheter should be at an approximate 45° angle on the LAO view and should be inferior and posterior to the pigtail catheter in the aortic root on the RAO view. However, it should be emphasized that no specific angle in the RAO or LAO projections will be anatomically consistent or correct in all patients. This is because of the relative differences in body habitus, cardiac position, and asymmetric cardiac chamber enlargement. Using the CS catheter, once placed, typically defines the annulus and the His bundle recording catheter defines the septum (when recording the His) and thus will allow appropriate adjustment of the RAO and LAO views respectively.

In the event of RA dilatation, it may be necessary to alter the curve of the BRK needle further. This may also be necessary in the event of a repeat procedure where fibrosis around the FO can make engagement of the dilator difficult. Additionally, if the needle is at the tip of the dilator when the dilator is advanced, it may ride up over the FO, and withdrawing the needle to 1.5 inches from needle guide to base of dilator will allow more give for the dilator to catch in the FO.

ICE can visualize the FO with high resolution (Figure 4), and ICE allows for the position of the needle relative to the FO to be confirmed. Once the dilator is in place and confirmed on ICE, the needle is advanced with a steady motion through the FO, watching for inadvertent angulation changes of the dilator(Figure 5). The pressure tracing should initially be blunted as the needle rests against the septum, then a sudden shift to an LA pressure is expected as the puncture is performed. At this point, contrast injection should confirm filling of the LA.

Some operators choose to stain the septum with contrast; however, the effect of this on future pressure measurements should also be considered as mentioned above.

Following confirmation of needle tip location, with the right hand steadying the needle, the dilator and sheath assembly is advanced smoothly over the needle. Some operators have used an angioplasty wire through the needle out of concern for the assembly prolapsing back through the septum. The needle is then removed and blood allowed to flow back through the dilator or via syringe suction. The 0.032 wire is then advanced through the dilator and directed either out the left upper vein or looped in the atrium to exit via the right upper vein. At this point, the sheath is advanced through the septum. Once the SL1 sheath is across the septum, the SL1 sheath then may be exchanged over a 0.032 wire to an Agilis Sheath if desired.

As this review highlights, a comprehensive understanding of the pertinent anatomy is critically important for performing transseptal punctures. Experienced operators may be able to navigate the anatomy using alternative means of guidance other than fluoroscopy. Thus, a transseptal puncture can be performed without fluoroscopy using other tools such as ICE and electroanatomic mapping.

Figure 4: An intracardiac echocardiography (ICE) image demonstrating the high resolution with which the fossa ovalis (FO) (*) can be visualized.

Figure 5: An illustration depicting an intracardiac echocardiography (ICE) probe within the right atrium (RA) visualizing the fossa ovalis (FO).
In the event of significant septal tenting or an aneurysmal anomaly, rotating the needle anteriorly as the puncture occurs will point the needle toward the left ventricle or appendage allowing for more room.

If the pressure waveform is blunted on advancement of the sheath, then it may be either against the lateral or posterior wall or stuck on the septum. In these circumstances, a contrast injection should be performed to clarify the catheter position, and it should be confirmed with ICE.

In patients with a fibrosed septum from previous transseptal puncture, an alternative technique is to utilize radiofrequency ablation to facilitate crossing the septum.

## Variations in technique

There is operator-dependent variation in technique between the use of a single or double transseptal puncture. In the event of a dual puncture, the second approach is directed immediately posterior to the first as guided by ICE and the process repeated as above.

For those using a single puncture, the wire is retained in the left atrium and the sheath and dilator assembly advanced and withdrawn across the septum several times. The assembly is then withdrawn into the IVC and the ablation catheter directed through the puncture site on fluoroscopy. The sheath and dilator assembly is then advanced several times again through the puncture site before the sheath is advanced over the wire and the dilator and wire withdrawn. The sidearm of the three-way tap is then opened and blood allowed to drain back, prior to syringe connection and flushing of the sheath, ensuring an air-free connection.

Although these differences are operator-dependent, there is some echocardiographic evidence of an increased tendency to iatrogenic atrial septal defect at 9 months post procedure with the single puncture technique, especially in patients with elevated pulmonary artery pressures at baseline.

### Practical points for the electrophysiologist
- Operators thorough with the regional anatomy of the interatrial septum can often modify the procedure to suit specific circumstances.
- Single or dual puncture techniques can be performed safely, the choice is predominantly the operator’s.
- Radiofrequency ablation or cautery either directly or with a specific needle is increasingly used in difficult cases but does not preclude the basic understanding of how to avoid complications with transseptal puncture.
- Over-the-wire access can also be considered, especially with a very plastic fossa or small atrium.

## Conclusion

Invasive electrophysiologists now most commonly perform transseptal puncture and require a thorough and intimate understanding of the regional anatomy as well as sheath management techniques to consistently and safely perform this procedure in a variety of patient types and with varying cardiac pathology.

## References
