Trans-septal catheterization for atrial fibrillation ablation

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Introduction

Since the first direct left atrial pressure recording in a patient with an atrial septal defect by Courmand et al.,1 different approaches such as the transbronchial2 and percutaneous apical left ventricle puncture3 methods have been used for obtaining the pressure of the left cardiac chamber in order to treat patients with various heart diseases. The current transseptal catheterization was first performed by Ross et al.,4 and the technique underwent several modifications since then, to meet the specific needs.5-7 Transseptal catheterization has been used for diagnostic purposes in valvular heart disease, however with the development of new non-invasive technologies such as 2-dimensional (D) echo/Doppler and cardiac MRI, the need for transseptal catheterization has greatly decreased since early 1990. The interest in the transseptal catheterization was revived by interventional cardiology in order to meet the needs of the new percutaneous therapeutic procedures such as mitral and aortic valvuloplasty, closure of atrial septal defects, left atrial appendage occlusion, and the recent mitral annuloplasty.

Transseptal catheterization was also revived by the interventional electrophysiology field and has been used to treat a variety of arrhythmias including left sided accessory pathways,8 left atrial or pulmonary vein origin atrial tachycardias,9,10 atrial fibrillation,11 and ventricular tachycardia.12 Thus, the transseptal catheterization technique was further modified in a unique way, and currently several transseptal techniques have been reported in the literature.13-17 With the recent advances in atrial fibrillation ablation, the double transseptal catheterization technique has become the cornerstone of atrial fibrillation ablation. Therefore, a proper transseptal catheterization is essential for a successful left atrial or ventricular arrhythmia ablation.

This article intended to review some of the important considerations for transseptal catheterization in the cardiac electrophysiology practice for patients with left atrial and ventricular arrhythmias.

Anatomical considerations

A comprehensive review of the normal atrial anatomy has been reported in the literature,18-20 and it is important to review that literature prior to mastering the technique. The atrial septum, in particular the anatomy of the fossa ovalis is the primary interest for the transseptal procedure. The fossa ovalis has an average diameter of 21 mm and
has a well defined distinctive limbic ledge in its superior, anterior and inferior margins. The limbic ledge has been used as the landmark for the transseptal left heart catheterization. The posterior margin is not well defined due to the lack of a distinctive ledge and has a gradual transition of the tissue thickness from a thick inferoposterior septum to a thin anterosuperior membrane (Figure 1). The clinical implications of these anatomical characteristics is that it would be much easier to engage the transseptal apparatus (sheath and needle) on the fossa ovalis with a posterior to anterior sweeping motion than with an anterior to posterior motion. This maneuver also avoids the confusion between the fossa ovalis and the crevices that often present in the anterior atrial septum which are located just opposite to the aorta.

Another important structure that should be recognized is the superior vena cava (SVC)-aorta groove. The SVC-aorta groove is formed by the most posterior margin of the ascending aorta and posteromedial wall of the SVC. During the craniocaudal dragging of the transseptal apparatus, the groove is easily recognized by rotating the transseptal apparatus in the horizontal orientation within the mid-SVC. The groove is located at the most medial portion of the SVC in left anterior oblique (LAO) projection of the fluoroscopy and the lower part of the groove leads into the fossa ovalis.

Clinical considerations

There are many variations in the cardiac anatomy among patients and those variations can directly influence the transseptal catheterization. As the patient population grows older, deformities of the

Figure 1. Anatomy of the fossa ovalis. Panel A and B show a right lateral view of the atrial septum to illustrate the fossa ovalis. The fossa ovalis is bordered by the limbic ridge in its superior and anterior aspects and by the eustasian ridge in its infero-anterior aspect. There is no clear border in infero-posterior aspect of it (black arrows) that may have a significant implication during the transseptal catheterization.
vertebrae and chest wall become much more frequent among them. The deformities of the chest wall including the sternum or vertebrae can often lead to anatomical changes in not just the heart, but also the major vessels. For example, severe scoliosis of the thoraco-lumbar vertebrae can create a significant difficulty in applying proper torque during the transseptal catheterization and it is impossible to perform the transseptal catheterization from the femoral veins (Figure 2A). However, if the patient has severe rightward scoliosis, the transseptal catheterization can be successfully performed from the left femoral vein. Thus, a comprehensive clinical examination is very important to appreciate these anatomical variations, especially those related to the chest or torso. Diseases of the great arteries such as an ascending aortic aneurysm or underlying lung disease can also alter the cardiac anatomy including the atrial septum orientation that directly influences the transseptal catheterization. It is also important to evaluate the patients with particular attention paid to the presence of a large hiatal hernia that could deform the posterior cardiac border and increase the risk for life threatening complications.

Three-D imaging such as computed tomography (CT) angiography or magnetic resonance imaging (MRI) are extremely helpful for evaluating the atrial

**Figure 2.** Examples of anatomical barriers for the transseptal puncture. Panel A shows a modified shape of the transseptal needle and dilator in a patient with severe scoliosis. Panels B and C show the different shaped IVC filters, which require caution when passing the transseptal sheaths. All abbreviations are as used in the text.
septal/fossa ovalis anatomy, patency of the proximal vessels, and vital adjacent non-cardiac structures especially in patients with an inferior vena cava (IVC) filter (Figure 2B, 2C) for a previous pulmonary embolism or the presence of a large hiatal hernia. Furthermore, 3-D imaging can diagnose unsuspected congenital defects such as atrial septal defects including the venous type, a persistent left SVC, or the total absence of an IVC. Therefore, it allows clinicians to plan and select the proper transseptal approach (femoral versus neck approach,21, 22 Figure 3) or another alternative therapy.

Technological considerations

1. Transseptal sheaths and dilators

Several companies manufacture different shapes of transseptal sheaths (Figure 4A). They can vary in length as well as in stiffness. There are braided and non-braided sheaths. The braided kind is much stiffer than the non-braided and can provide much more support during the puncture of the fossa ovalis (Figure 4A 3,4). Therefore, the braided sheaths are useful for puncturing a thicker fossa ovalis and for

Figure 3. Shows a transseptal puncture through the internal jugular vein due to a thrombotic obstruction of the IVC. The transseptal sheath is advanced into the interatrial septum and a sudden drop at the limbic ledge can be seen (A). After passing the needle, a contrast agent reveals the lower left atrial wall (B, white arrow). The transseptal sheath can be placed in the LA over the needle and dilator (C), and mapping and ablation can be performed successfully (D). All abbreviations are as used in the text.
applying greater torque to the ablation catheter. The most popular, commonly used sheaths were developed by Dr. John Swartz in the early 1990’s to target the variety of left sided accessory pathways and those sheaths are quite useful for the ablation of left atrial and ventricular arrhythmias including atrial fibrillation. Some of them however need to be exchanged after performing each successful transseptal catheterization with a traditional Mullin’s sheath due to its unique shape. The majority of the centers use these sheaths as part of the primary apparatus for performing the transseptal procedure and this eliminates the need for an exchange, and results in cost savings, a reduced procedure time, and a lower complication rate. The most widely used sheaths are the SL-1 (Fast-Cath guiding introducer, St. Jude Medical, Inc., St. Paul, MN, USA) and Preface® (Biosense Webster, Inc., Irwindale, CA, USA), and it is possible to reach more than 99% of the target sites on the left side with those sheaths. Recently several companies have developed deflectable guiding sheaths (9.5 F to 11 F) that can be exchanged after the initial transseptal catheterization with a smaller sheath. These sheaths have physical characteristics of being large in diameter and significantly stiffer than the conventional standard 8 to 8.5 F sheaths. We do not use these sheaths routinely in our laboratory due to

Figure 4. Panel A shows the most commonly used transseptal sheaths and dilators; Mullin sheath (1), SL-2 sheath (2), SL-1 sheath (3), and Preface sheath (4). The braided sheath has different colors at its tip (3,4). Panel B shows the material scraped from the dilator by the transseptal needle. There are several manufactured transseptal needles with different shapes and lengths (C). All abbreviations are as used in the text.
the increased risk of perforation, groin complications, and costs. They are reserved for patients with an extremely difficult anatomy that standard sheaths fail to allow reaching the target area.

The dilators are provided with the sheath and they also have a wide range of physical characteristics that may become important during the transseptal catheterization. In particular, the dilator’s stiffness and inner lumen diameter are the most important factors for a safe needle placement. We observed a significant incidence in scrapping the inner surface of the dilator during the transseptal needle insertion. This scrapping is due to a mismatch the size of the needle and dilator (Figure 4B). The scrapping will result in a difficult protruding of the needle beyond the dilator tip during the puncture, and an early thrombus formation may occur. To avoid this problem, we recommend pre-loading the transseptal needle into the dilator to test the proper match between the dilator and needle before inserting it into the patient’s body.

2. Transseptal needles

There are several manufactured transseptal needles currently available. They can vary in shape and length (Figure 4C). The proper needle curvature is also essential to avoid any complications and to achieve an ideal transseptal puncture.

3. X-ray equipment

Many cardiac catheterization laboratories are equipped with a full range of motion (180°) fluoroscopy. The interventional cardiologist often uses bi-plane cine fluoroscopy to perform transseptal punctures using anteroposterior (AP) and left lateral views. In our laboratory, we use single plane cine fluoroscopy and the usual range of fluoroscopy is between RAO 45 and LAO 45. The fluoroscopic angles for each patient vary depending on the orientation of the atrial septum.

4. Transesophageal echocardiography (TEE) or intracardiac echocardiography (ICE)

TEE: Because of the required intubation to protect the airway during the early experience with this technique and the resulting discomfort for the patient, routine use of TEE become quickly unpopular. The TEE probe blocks the view of the upper region of the left atrium (LA), and the inferior pulmonary veins cannot be visualized well.

ICE: Many institutions in the US and Europe have been practicing the routine use of ICE to guide the transseptal catheterization. Obviously, the use of ICE adds an additional safety margin by confirming the engagement of the transseptal apparatus into the fossa ovalis, and can offer early detection of complications such as a hemopericardium.

However, due to the small real time 2-D visual field, it often cannot confirm the ideal puncture site within the fossa ovalis. Furthermore, routine use in developing countries adds a high additional cost and requires a minimum of a 9F sheath to place the ICE catheter which can cause more vascular and bleeding complications. We have reserved the use of ICE for complex congenital cardiac patients in order to guide not just the transseptal procedure, but also to evaluate the complex cardiac anatomies.
boembolisms. There are two practical options to consider for these high risk patients. The first is the continuous administration of oral anticoagulants until the procedure day. The second option is to discontinue warfarin 3 days before the procedure and bridge that time with low molecular weight heparin. Currently, many centers in the US do not stop the oral anticoagulants before the atrial fibrillation ablation and the procedure is performed with an INR level between 2.0~2.5. This can avoid any inconvenience, such as bridging with low molecular weight heparin before and after the procedure, and can be cost saving for the patients.

We have been using a continuous oral anticoagulation strategy for the last year and it has improved the patient’s comfort without increasing the incidence of bleeding complications such as a hemopericardium. This approach is particularly useful in patients with mechanical heart valves, and can shorten their hospital stay.

2. Direct pressure monitoring

We do not use routine arterial cannulation for blood pressure monitoring during the transseptal catheterization, but the majority of the ablation centers prefer direct arterial pressure monitoring. However, during the transseptal puncture, we monitor the pressure from the transseptal apparatus directly to confirm the left atrial access. Therefore, only one pressure monitor system is used.

3. Heparinization during the transseptal catheterization

We do not heparinize the patients until the transseptal catheterization is completed but an exception is considered in cases when the second transseptal puncture is delayed for more than 15 minutes. We have not observed a significant increase in the thromboembolic complications related to transseptal catheterizations but some centers have been using a heparinization strategy prior to the transseptal catheterization. The usual recommended heparin loading is 100 unit/Kg of bodyweight.

4. Transseptal catheterization techniques

Before the transseptal catheterization, we recommend always to obtain a baseline cine image of the motion of the left cardiac border in the LAO projection so that one can compare it throughout the procedure. This will allow identifying any significant pericardial fluid accumulation and may prevent a full-blown, hemodynamically unstable pericardial tamponade.

There are several different techniques for performing a transseptal catheterization in terms of the number and shape of the sheaths used, and the number of actual transseptal punctures which varies from one to three.¹⁶, ²³ We employ a technique with separate double punctures using braided SL-1 (Fast-Cath guiding introducer, St. Jude Medical, Inc., St. Paul, MN, USA) and Preface® (Biosense Webster, Inc., Irwindale, CA, USA) sheaths and a standard size transseptal needle that can be shaped according to the patient’s atrial anatomy (size or volume). A longer sheath and needle are required for patients with a large body mass index (weight >125 Kg, height >190.5 cm), but such patients are rare among Asian populations except for acromegalic patients who are known to develop atrial fibrillation. The transseptal sheaths need to be prepared carefully before insertion into the patient’s vascular space, and special attention is needed to avoid scrapping the dilator while introducing the transseptal needle.

We believe that these scrapped-off plastic
materials are highly thrombogenic and possibly responsible for the early thrombus formation observed in ICE studies during transseptal catheterizations.

The sequence of the transseptal catheterization is shown in Figure 5. The stepwise techniques are as follows:

1) Place the guide wire into the left subclavian vein.

2) Advance the sheath into the left subclavian vein over the guide wire to avoid inadvertent SVC injury or perforation.

3) Remove the dilator and guide wire.

4) Aspirate and flush the sheath to eliminate any dead space within the sheath.

5) Load the transseptal needle with the stylet into the dilator on the preparation table to test for a

Figure 5. Shows the transseptal catheterization sequence. 1) Place the guide wire inside of the left subclavian vein. 2) Advance the sheath into the left subclavian vein over the guide wire. 3) Remove the dilator and guide wire. 4) Advance the dilator with the needle inside. When the dilator approaches the tip of the sheath, pull the sheath back and lock it to the dilator. 5~6) Rotate the transseptal apparatus anterior and posteriorly to find the most medial direction. 7~8) Being dragged continuously, the transseptal apparatus will move medially (toward the LA) with a sudden distinctive leftward motion. 9) The ideal puncture site for AF ablation is a distance of 40% from the posterior margin of the left atrium and 60% from the CS catheter. 10) The transseptal needle is advanced toward the left main bronchus in the LAO view while monitoring the pressure. 11~12) Once a successful puncture of the fossa ovalis is confirmed, then the dilator with the sheath is advanced over the needle, and the dilator with needle is removed. All abbreviations are as in used the text.
smooth transition without any scraping. Then, remove the stylet and the stopcock of the needle hub should be locked after flushing.

6) Load the dilator with the needle inside into the sheath which has already been placed in the left subclavian vein. When the dilator approaches the tip of the sheath, pull the sheath back and lock it to the dilator to avoid inadvertent vessel injury from advancing the dilator.

7) The transseptal apparatus (sheath, dilator and needle) is flushed before connecting it to the pressure monitor system.

8) The transseptal apparatus is withdrawn gradually and pointed toward the atrial septum in the LAO view (recommended LAO angle: the His bundle catheter is pointing directly toward the operator). It is important to identify the SVC-aortic groove that is formed by the posterior margin of the ascending aorta. The best region to identify the groove is the mid-level of the SVC, and the groove is located at the most medial portion of the SVC in the LAO view which can be identified by rotating the transseptal apparatus anteriorly or posteriorly (clockwise or counter-clockwise motions).

9) Being dragged continuously, the transseptal apparatus will move medially (toward the LA) with a sudden distinctive leftward motion when it engages into the fossa ovalis and this distinctive leftward motion of the transseptal apparatus is appreciated better in the LAO view than the PA or right anterior oblique (RAO) views. Occasionally, some patients have large sized crevices at the anterior atrial septum which can be confused for the fossa ovalis. This can be differentiated from the fossa ovalis confirming in the RAO view that the transseptal apparatus is in the posterior septum: fossa ovalis.

10) The final adjustment is done in the RAO view (recommended RAO angle: coronary sinus (CS) catheter is perpendicular to the operator) where one can appreciate the anterior margin (CS catheter) and posterior margin of the cardiac silhouette.

11) The transseptal apparatus can be rotated anteriorly or posteriorly to reach the final puncture site that the operator desires within the fossa ovalis. The ideal puncture site is illustrated in Figure 6 (a distance of 40% from the posterior margin of the LA and 60% from the CS catheter).

12) The transseptal needle is advanced toward the left main bronchus in the LAO view while monitoring the pressure to confirm the puncture of the fossa ovalis. If there’s no immediate LA pressure recording after the puncture, a small volume of contrast agent is injected through the needle to confirm the needle position in relation to the septum or LA cavity.

13) An inadvertent puncture with the transseptal needle (but not the dilator) of undesirable sites such as the ascending aorta, septum or posterior wall have not been associated with major complications.
Figure 6. Shows the ideal transseptal puncture site for atrial fibrillation ablation. The recommended RAO angle is that with the CS catheter perpendicular to the operator (A). In the RAO projection, the distance between the posterior margin of the LA (arrow head) and CS catheter can be easily measured. The ideal puncture site for AF ablation is a distance of 40% from the posterior margin and 60% from the CS catheter in the RAO view. The recommended LAO angle is that with the His bundle catheter pointing directly toward the operator (B). After engagement of the transseptal apparatus into the fossa ovalis, the apparatus should be advanced toward the left main bronchus (arrow). RA: right atrium. The other abbreviations are as use in the text.

Figure 7. Shows an anteroinferior and superoposterior double transseptal puncture. The first transseptal puncture site is selected at a superior and posterior site of the fossa ovalis (A, A'). The 2nd transseptal puncture can be placed at a site 5 ~ 10 mm anteroinferior from the first puncture site (B, B'). The two well separated transseptal sheaths can provide various accesses to the pulmonary veins (C, C'). The top row shows the RAO projection of the fluoroscopy and bottom row the LAO projection of each step. All abbreviations are as used in the text.
14) Once a successful puncture of the fossa ovalis is confirmed then the dilator with the sheath is advanced over the needle and the dilator with the needle is removed.

15) Approximately 5~6 mL of blood is aspirated from the sheath and is then flushed.

16) The 2nd transseptal puncture can be placed at a site 5~10 mm anteroinferior or posterosuperior from the first puncture site (Figure 7). A posterior puncture is essential for accessing the low posteriorly located right inferior pulmonary vein and inferoposterior region of LA. The anterior puncture is for the anteriorly located superior pulmonary veins of LA during the procedure.

A few techniques for specific conditions

1. Patent foramen ovale (PFO)

We do not use a PFO as an access for the transseptal approach for atrial fibrillation ablation due to the lack of septal support for the transseptal sheath, which causes the catheter placement to be unstable. Thus, the transseptal sheath is placed through a puncture of the intact portion of the fossa ovalis.

2. The accidental migration of the transseptal sheath into the right atrium

The transseptal sheath and ablation catheter can be accidently or purposely pulled back into the right atrium during the ablation procedure, especially for ablation of the right pulmonary veins. In the majority of cases, the sheath can be placed back through the same puncture site using the ablation catheter.

3. Difficulty in manipulating the transseptal sheath and ablation catheter

From time to time, we encounter a significant difficulty in manipulating the ablation catheter and transseptal sheath during the procedure. It is often due to an undesirable transseptal puncture site: too anterior from the ideal site. We recommend a careful evaluation of the transseptal puncture site, and a re-puncture at an ideal site as soon as the problem is identified. This will minimize the procedure time and avoid complications.

4. Thick membrane of the fossa ovalis

Occasionally, we encounter patients who have a myxomatous membrane of the fossa ovalis that can be quite thick and cannot be punctured with the standard needle. Recent studies report that it is helpful and safe to use a radiofrequency current delivery from a standard electrocautery device in conjunction with a standard transseptal needle in order to make a small hole in the atrial septum and then advance the transseptal apparatus. This approach can be useful in failed standard transseptal punctures, but we do not use it in routine practice.

Special conditions

It is not uncommon to encounter patients who have received several cardiovascular devices for the treatment of underlying diseases and have been referred for a catheter ablation that requires transseptal catheterization.

1. Pacemakers and implantable cardioverter defibrillators (ICDs)
The most common device that we encounter during the transseptal catheterization is a pacemaker or ICD. The transvenous leads of these devices can often create obstacles during the transseptal catheterization. The transseptal apparatus needs to be medial to the leads in the LAO view in order to avoid entanglement (Figure 8A).

### 2. Septal closure devices

There are two major brands of septal closure devices that have been implanted in the atrial septum for atrial septal defects (ASDs) or PFOs. Each one has different sizes and shapes. A careful review of the implant record prior to the procedure is essential and an ICE-guided transseptal puncture is recommended. The common successful puncture site is the inferoposterior margin of the closure device (Figure 8B), and no more than one transseptal sheath should be placed.

### 3. ASD surgical repairs

Patients, who have undergone a surgical ASD repair and have an absolute need for a transseptal catheterization, should be referred to an experienced center for this type of patient. In our experience, Dacron grafts are the most difficult structures to penetrate with the transseptal needle and the sheath, and catheter manipulation is extremely limited and difficult. Pericardial patches can be accessed with a standard needle but the success rate of the puncture appears to get lower as the patch gets older due to the extensive scarring and fibrosis of the patch.

### 4. IVC filters

It is not uncommon to encounter patients with an IVC filter in our practice. Most IVC filters can be crossed safely with electrophysiological catheters and transseptal sheaths. All long sheaths should be passed over the guide wire with the dilator with caution, under fluoroscopic visualization during the

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**Figure 8.** Special conditions to consider during the transseptal puncture. The transseptal apparatus needs to be medial to the pacemaker or ICD leads (arrows) in the LAO view in order to avoid entanglement with the leads (A). The patients with atrial septal occluders can be candidates for a septal puncture. A common successful puncture site is the inferoposterior margin of the closure device (arrow in B). All abbreviations are as used in the text.
insertion as well as during the removal (Figure 2B, C). These patients may also have significant femoral or iliac vein sclerosis from previous thromboembolic events that can result in an unsuccessful femoral vein cannulation. The IVC filter may limit the transseptal apparatus manipulation during the transseptal puncture but there have been no major difficulties in the majority of cases.

Conclusions

The transseptal catheterization is becoming an integral part of the interventional electrophysiology practice. However, the transseptal catheterization technique used in electrophysiology is being differentiated from interventional cardiology due to the different purposes and objectives of the procedures. Therefore, it is important to understand the atrial anatomy, especially the interatrial septum, completely before practicing the transseptal catheterization. The transseptal catheterization can be practiced safely and efficiently for the treatment of cardiac arrhythmias.

References

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