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ATRIAL FIBRILLATION

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Mark J Earley

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The left atrium (LA) is the most difficult cardiac chamber to access percutaneously. Although it can be reached via the left ventricle and mitral valve, manipulation of catheters that have made two 180° turns is cumbersome. The transseptal puncture permits a direct route to the LA via the intra-atrial septum and systemic venous system. Previously the technique was used infrequently by cardiologists for mitral valvuloplasty and ablation in the left heart; however, the explosion of interest in catheter ablation of atrial fibrillation (AF) has meant the transseptal puncture is a routine skill of the modern cardiac electrophysiologist. This article looks at the practical aspects of this important procedure, particularly as applied to the cardiac electrophysiologist.

HISTORY

The transseptal puncture was developed by Ross, Braunwald and Morrow at the National Heart Institute (now the National Heart, Lung, and Blood Institute), Bethesda in the late 1950s to allow left heart catheterisation, principally for the evaluation of valvular heart disease.¹ Early problems were difficulty cannulating the left ventricle, injecting sufficient volume of contrast for imaging, and inadvertent aortic puncture. Important refinements were made to the needle and catheter such that Brockenbrough's description of the technique in 1962 differs little from that used now.² Mullins developed a combined catheter and dilator set designed precisely to fit over the Brockenbrough needle, which gives a smooth taper from the tip of the needle, over the dilator to the shaft of the sheath.³ The terms Brockenbrough needle and Mullins sheath are often used by operators generically when referring to transseptal needles and sheaths, respectively; however, there is a range of equipment available from several manufacturers, often designed for specific applications—for example, catheter ablation of AF.

INDICATIONS

Access to the LA is needed for catheter ablation, percutaneous mitral valvuloplasty, and occasionally left heart catheterisation where an accurate haemodynamic assessment of the mitral valve is needed or where access to the left ventricle (LV) is denied by a prosthetic aortic valve. Catheter ablation accounts for the vast majority of these cases and in our institution transseptal puncture

has been performed in 651 patients in the electrophysiology (EP) laboratory in the past 2 years (fig 1). Transseptal access is widely used for accessory pathway and ventricular tachycardia ablation; however, the huge increase in its use is due to AF cases.⁴

Radiofrequency ablation of atrioventricular accessory pathways that span the mitral valve annulus can be performed via a transseptal puncture (anterogradely) or via the aorta and left ventricle (retrogradely). Observational studies that have compared the two routes have not shown any differences in safety or effectiveness.^{5–7} Cardiologists, familiar with left heart catheterisation and coronary angiography, are comfortable using catheters in the aorta and left ventricle and therefore some electrophysiologists prefer the retrograde approach. Once a successful transseptal puncture is made, however, manipulation of the ablation catheter on the mitral valve (MV) annulus is far easier anterogradely, and with the transseptal puncture becoming a routine skill it is likely to become the approach of choice.

TECHNIQUE

Patient preparation

The operator needs to keep in mind that cardiac tamponade is a potential hazard to the transseptal puncture and the patient should start the procedure optimally prepared. Preoperative fasting is necessary but the patient should not be dehydrated and if necessary intravenous fluids are given. A peripheral intravenous cannula inserted before entry to the lab allows delivery of sedation and emergency drugs in the event of a profound vagal reaction. Both inguinal areas are prepared and draped, with access to the femoral veins gained using the Seldinger technique. At least one short femoral sheath needs to be reserved for the delivery of central venous fluids in an emergency. If a 7 French sheath or larger is used this sheath allows access for a 6 French electrophysiology catheter.

Before AF ablation a transoesophageal echocardiogram (TOE) is commonly performed to ensure the LA is free of thrombus. The scan should be reviewed by the physician performing the transseptal puncture to gain as much knowledge regarding the anatomy of the intra-atrial septum (thickened or aneurysmal) and size of the atria. The presence of a persistent foramen ovale or atrial septal defect is also noted.

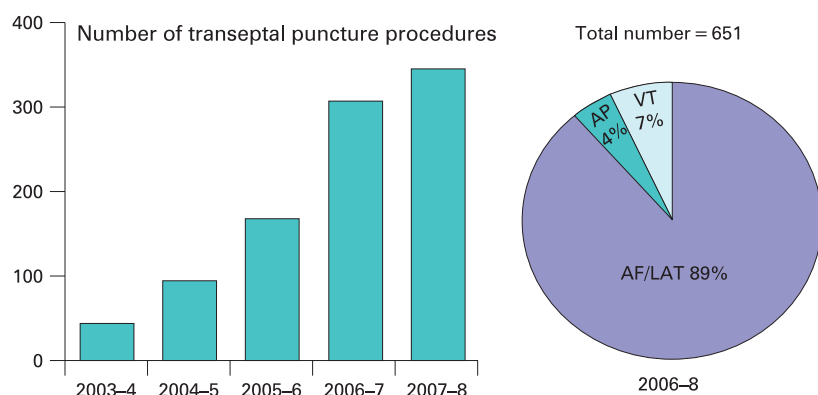


Figure 1 The left hand bar chart shows the number of electrophysiological procedures during which a transseptal puncture was performed during the financial year (April–March) at St Bartholomew's Hospital, London. The pie chart depicts the ablation procedure performed for all 651 transseptal punctures from April 2006 until March 2008. There has been a massive expansion in the number of transseptal punctures which mirrors the growth in catheter ablation of atrial fibrillation. AF/LAT, atrial fibrillation or left atrial tachycardia; AP, accessory pathway; VT, ventricular tachycardia.

Equipment

The transseptal puncture kit consists of a long pre-shaped plastic sheath, introducer and the needle (fig 2). Safe technique depends on having a lumen through the centre of the needle to allow pressure monitoring and delivery of contrast. Care must be taken to ensure needle, dilator and sheath are all compatible and licensed for use together. Standard sheath, dilator and needle lengths are 63, 67 and 71 cm, respectively; however, longer sets are available for tall patients and shorter sets for paediatric work. It is also advisable to check the relationship between the curve of the sheath and the side arm at the hub of the catheter, which will either be matching or opposite (that is, the sheath curves 180° away from the side arm).

Defining the anatomy of the intra-atrial septum

The intra-atrial septum is bounded posteriorly by a fold of pericardium between the left and right atria, superiorly by the superior vena cava (SVC), antero-superiorly by the non-coronary sinus of Valsalva in the aortic valve, anteriorly by the septal tricuspid annulus, antero-inferiorly by the coronary sinus os, and inferiorly by the inferior vena cava. By far the most important structure to avoid puncturing is the aortic valve and root. Most operators therefore use an intracardiac catheter to provide an anatomical marker of the aortic valve. The most accurate is a pigtail catheter advanced to the aortic root from the femoral artery (fig 3). Although arterial access increases the chances of complications, particularly femoral haematoma, it allows accurate monitoring of arterial pressure throughout the procedure. Alternatively a diagnostic electrophysiology catheter can be used to mark the bundle of His which is positioned close to the aortic root or the coronary sinus os, which lies in the same vertical plane as the aortic root when viewed in the right anterior oblique (RAO) projection (fig 3). By keeping the transseptal puncture

posterior to any of these markers a potentially fatal aortic perforation will be avoided.

Procedure

The procedure is described using a Brockenbrough needle. Another option is the Endry's double needle set which is not discussed here. All the equipment is flushed with heparinised saline and assembled. The sheath and dilator are advanced over a 135 cm 0.035 or 0.032 inch J tipped guide wire into the SVC. The guidewire is removed and, after aspiration and flushing of the lumen, exchanged for the needle which can be guided through the transseptal dilator over a protective stylet. Particular care needs to be taken in non-braided equipment as perforation of the needle through the side of the dilator and sheath is possible if a stylet is not used. The tip of the needle must be kept within the lumen of the dilator to avoid inadvertent puncture of the SVC; this is achieved by always keeping the hub of the needle two fingers width back from the hub of the sheath (fig 2). After removal of the stylet the needle is aspirated and attached to a continuously flushing heparin saline bag which is transducing pressure.

For the puncture the needle should be held in the fingers of the right hand, with the left hand holding the sheath and dilator controlling movement of the whole assembly (fig 4). With the x ray positioned at 30° left anterior oblique (LAO), the sheath and catheter are rotated so that both are pointing approximately to the 4–5 o'clock position (fig 4). The whole assembly is then withdrawn smoothly towards the patient's feet while observing the catheter movement on x ray. The first movement seen will be the catheter falling into the right atrium (RA) from the SVC and then there will be a second more subtle movement as the catheter falls from the thicker muscular intra-atrial septum into the fossa ovalis. The assembly should then be gently advanced and if in the correct position it may catch on the lip of the fossa. At this point the pressure tracing should demonstrate a higher pressure with a straight line suggesting the tip of the catheter is abutting the intra-atrial septum, thus damping the pressure tracing (fig 5). In this position (fig 6) the tip of the catheter will be superior to the proximal coronary sinus catheter (if used) and inferior to the pigtail catheter in the aortic root (if used). While keeping the assembly steady in the hand the x ray should then be swung around to 40° right anterior oblique (RAO) to ensure that the tip of the catheter is posterior to the mouth of the coronary sinus, His bundle or aortic catheter. If a coronary sinus catheter is used the needle should appear to run parallel to this (fig 6). If the needle does not catch the lip of the fossa ovalis and slides easily back up into the superior RA, then the whole assembly should be rotated slightly clockwise or anticlockwise and withdrawn again.

The puncture should be performed in the LAO projection. Using the right hand the needle is advanced into the transseptal sheath which is held

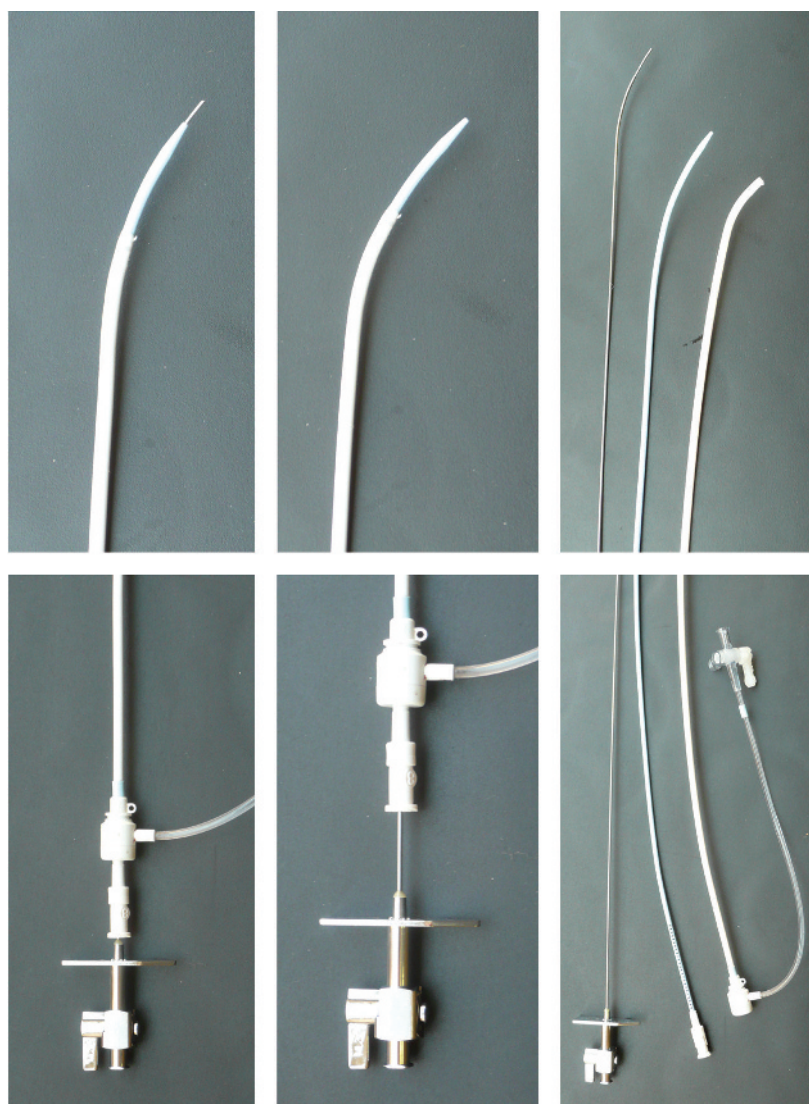


Figure 2 The right hand images show the three separate components of the transseptal assembly; the needle, dilator and sheath. These are 71, 67 and 63 cm long, respectively. The side arm at the hub of this sheath is pointing in the same direction as the curve at the tip of the sheath. The centre images show the assembly together with the needle back within the tip of the dilator. By keeping the hub of the needle two fingers width back from the hub of the dilator, the needle will not be exposed at its tip. In this position the assembly is moved to find the fossa ovalis. The left hand image shows the hub of the needle fully advanced into the dilator such that its tip is fully protruding, causing puncture of the fossa ovalis.

steady with the left hand. This is observed on x ray and the slight give as the needle suddenly jumps across the septum can be felt. At this point a change in the pressure waveform from damped to a left atrial pressure should be seen (fig 5). Before advancing the dilator or sheath across it is critical to be sure the needle is in the LA. If there is any doubt then the position should be checked by removing the pressure line and connecting a Luer lock syringe with contrast. Blood is then aspirated to de-air the needle and contrast injected to check the position of the needle. Once satisfied that the needle is in the LA it is fixed with the right hand while the dilator and sheath are advanced with the left hand. The give as the dilator crosses the septum is felt and observed on x ray. The dilator and needle are then fixed with the right hand and the sheath is advanced into the LA. If a pressure transducer has been attached throughout then LA

pressure should be seen when both the dilator and sheath are advanced. Loss of LA pressure suggests either the apparatus is against the back wall of the LA or that it has prolapsed back into the RA. Finally the dilator and needle are gently withdrawn, and blood aspirated through the side arm of the transseptal sheath to remove any air which is then connected to the continuously flushing pressure line.

An alternative approach, rather than continuously monitoring pressure, is to have a Luer lock syringe of contrast attached to the end of the needle. At the point when the needle is thought to be up against the fossa contrast is gently injected. If in the correct position tenting of the intra-atrial septum will be seen and then the needle can be advanced from the sheath dilator as described above. Contrast is then injected again to confirm the tip of the needle is in the LA. It is important to

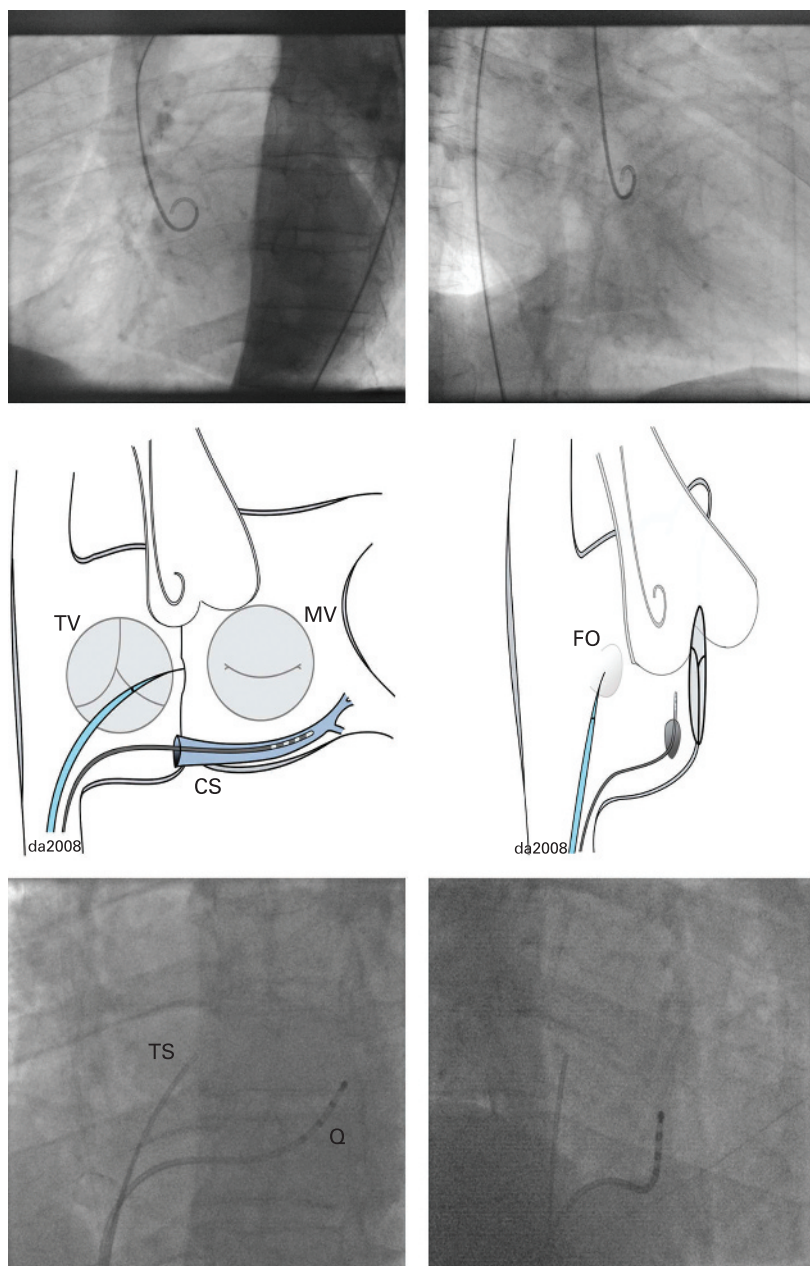


Figure 3 Marking anatomical structures with intracardiac catheters to prevent inadvertent puncture of the aortic valve. The left hand figures are in the left anterior oblique (LAO) and the right hand in the right anterior oblique (RAO) projections. The top row are fluoroscopic images of a pigtailed diagnostic catheter positioned in the aortic root; the middle row a diagram showing the transseptal needle in blue positioned on the fossa ovalis; and the bottom row fluoroscopic images of a transseptal needle on the fossa ovalis guided by a quadripolar diagnostic electrophysiology catheter in the coronary sinus. In the diagram a pigtail and coronary sinus catheter have been drawn. In the RAO projection it is vital to keep the tip of the needle posterior to the pigtail or running parallel to the coronary sinus catheter to avoid puncturing the aortic root. See the main text for more details. CS, coronary sinus; FO, fossa ovalis; MV, mitral valve; Q, quadripolar catheter; TS, transseptal needle; TV tricuspid valve.

remember that the lumen of the Brockenbrough needle is so fine that once contrast has been injected through it, intracardiac pressures cannot be reliably transduced without removing the needle and manually flushing it with a syringe of saline.

If it is necessary to have two sheaths in the LA—for example, to deliver an ablation and pulmonary vein mapping catheter for an AF procedure—then a second puncture can be made using the same technique. An alternative approach is to make the first puncture, withdraw the needle and pass a 0.032 inch exchange length guidewire up through the lumen of the dilator, anchoring it in one of the left pulmonary veins. The sheath and dilator are then withdrawn into the RA and a deflectable ablation catheter is manipulated through the hole in the intra-atrial septum alongside the guidewire. Once in position the sheath and dilator are advanced back over the guide wire into the LA. This technique has been widely used in AF ablation without difficulty⁸; however, it may be associated with a higher incidence of iatrogenic atrial septal defects (ASD).⁹

Anticoagulation protocol

The introduction of sheaths and catheters in to the left side of the heart exposes the patient to the risk of stroke. This is minimised by effective anticoagulation, usually with intravenous heparin and meticulous attention to de-airing and flushing of sheaths. Intracardiac echocardiography (ICE) images of transseptal sheaths have demonstrated that thrombus can build up within a few minutes, hence anticoagulation needs to be given promptly.¹⁰ In our institution 5000 units of heparin are given when the transseptal sheaths are introduced into the right heart and a further 5000 units given after the puncture(s) have been successfully completed. The activated clotting time is checked at 15 min and then every 30 min throughout, aiming to keep it above 300 s.

TROUBLESHOOTING AND ALTERNATIVE TECHNIQUES

There is much anatomical variation in the intra-atrial septum and consequently the transseptal needle may not always fall into the fossa ovalis. If patients have a large RA it is usually necessary to reshape the needle to give it a greater curvature. Many operators routinely do this for all transseptal punctures and needles with a greater curvature than the standard are available.

If this fails RA angiography can be used to delineate the anatomy of the septum.¹¹ To achieve satisfactory images a volume of 30 ml of contrast is injected into the RA at 12–15 ml/s using a power injector via a pigtail catheter in both the RAO and LAO projections. A hand injection via a sheath is an alternative. This will delineate the vena cavae, tricuspid valve, posterior wall of the RA and the intra-atrial septum. The stored images can then be used to guide the transseptal puncture. This technique is very useful where abnormal cardiac anatomy is found, for excessive rotation of the heart such that the needle has to be rotated far away from the usual 4–5 o'clock position, or when the right hemidiaphragm is elevated giving the impression that the needle is too low.¹¹

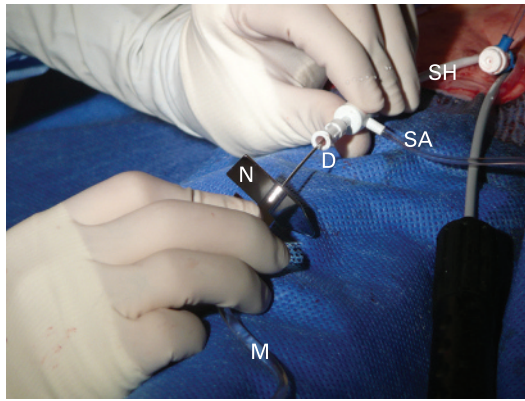


Figure 4 Photograph showing how the transseptal assembly is handled as described in the text. Note how the needle and side arm of sheath are both pointing to 4 o'clock (on an imaginary clock face in the transverse plain of the patient, hence 12 is anterior, 3 left, 6 posterior and 9 right). D, dilator of sheath; M, manometer line recording pressure from the tip of the needle; N, transseptal needle; SA, side arm of sheath; SH, transseptal sheath.

Ultrasound guided transseptal puncture

Direct visualisation of the intracardiac anatomy during the puncture, although never proven in a randomised controlled trial, is logically safer and more effective. It also gives confidence to proceed in difficult cases—for example, previous failures, unusual anatomy,¹² presence of prosthetic material or when the patient has a therapeutic international normalised ratio (INR).¹³ Small published series of ICE guided punctures^{12 14 15} report no complications compared with 1% for those guided fluoroscopically (see below).

An ICE probe is positioned in the RA via an additional 9 French short femoral vein sheath and directed to visualise the intra-atrial septum (fig 7). As the catheter and needle assembly are withdrawn the movement of the tip can be observed by ICE as well as fluoroscopy. Once the characteristic drop of the tip into the fossa ovalis is seen fine adjustments can be made to ensure that by ICE the

tip is at the thinnest part of the fossa. The dilator is advanced and the fossa is clearly seen to tent into the LA. The distance between the tip of the dilator and the posterior LA wall is observed, and to prevent inadvertent puncture of the wall fine adjustments are made to maximise this distance. The needle is then advanced as described above and on echo the tenting is suddenly seen to disappear as it punctures the septum.

A much cheaper alternative to ICE is to have a TOE probe in place for the puncture as in most cases images are as accurate as ICE (fig 7). If the ablation procedure is being performed with local anaesthetic and conscious sedation it adds considerable inconvenience for both the patient and operator; however, it is a very helpful technique particularly where a previous attempt had failed.

Angioplasty wire

An additional safety option is to advance a 0.014 inch angioplasty guidewire through the lumen of the angioplasty needle after initial puncture.^{16 17} If in the LA, the wire can be advanced into one of the left pulmonary veins where it is anchored. If the wire is not seen to pass outside the cardiac silhouette, looping around the pericardial space, or follows the course of aorta, then the wire should be withdrawn and dye injected to confirm location. The guidewire also provides some stability to the needle which aids passage of the dilator and sheath into the LA.

Radiofrequency ablation through the atrial septum

In as many as 40% of patients undergoing AF ablation a repeat procedure and therefore transseptal puncture is necessary. Crossing the atrial septum may be more difficult because of distorted anatomy or increased septal thickness caused by the previous puncture. One study reported 30% of repeat punctures being difficult.¹⁸ Where a puncture cannot be achieved in the standard way it is possible to use radiofrequency energy, delivered via

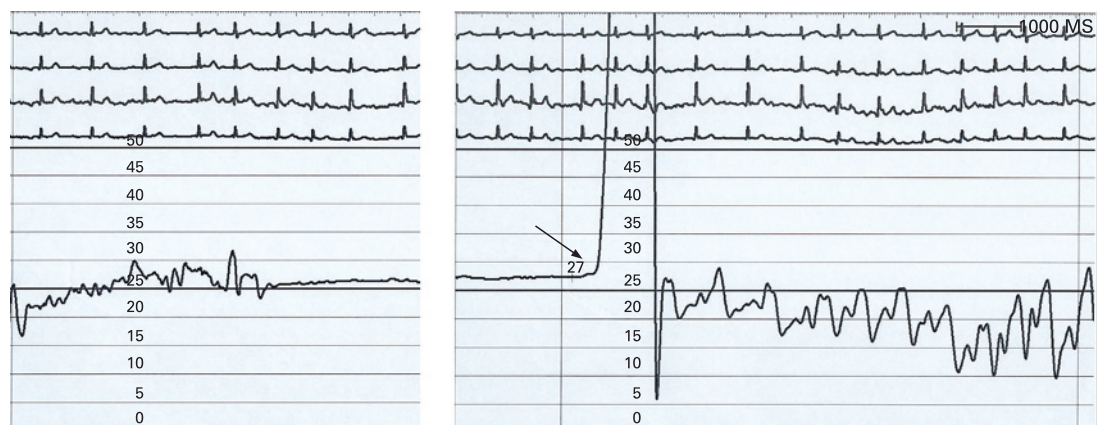


Figure 5 Pressure tracing from the tip of the transseptal needle during a successful puncture of the intra-atrial septum. The pressure scale is from 0–50 mm Hg with each gridline representing 5 mm Hg. The patient is in atrial fibrillation as can be seen from the ECG tracings at the top of the page. As the assembly is pulled down from the superior vena cava to the right atrium and into the fossa ovalis, the pressure tracing gradually dampens and then becomes a straight line to indicate the dilator is abutting the septum. When the puncture is made (arrow) there is a sudden elevation of pressure as the needle passes through the septum before a definite left atrium pressure wave is seen.

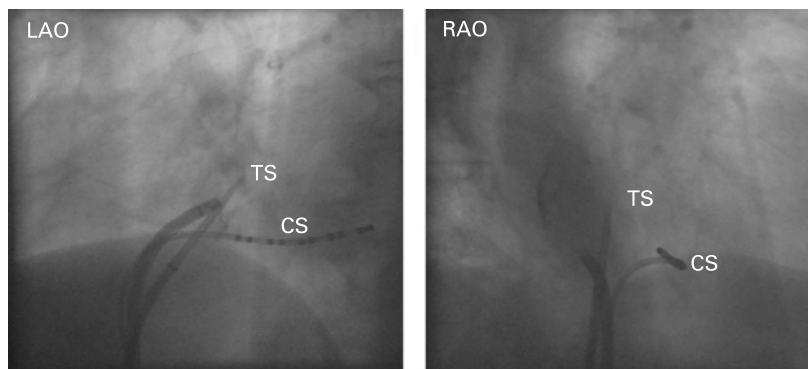


Figure 6 Fluoroscopic images demonstrating the correct positioning of the transseptal assembly (TS) on the fossa ovalis using a decapolar coronary sinus (CS) catheter as an anatomical guide. The proximal poles of the catheter have been positioned at the os of the CS. A second sheath is also visible in the right atrium. In the left anterior oblique (LAO) projection the needle is pointing medially and is superior to the CS os. In the right anterior oblique (RAO) projection it can be appreciated that the needle is posterior to the CS os and runs approximately parallel to the decapolar catheter. By confirming this position inadvertent puncture of the aortic root is avoided.

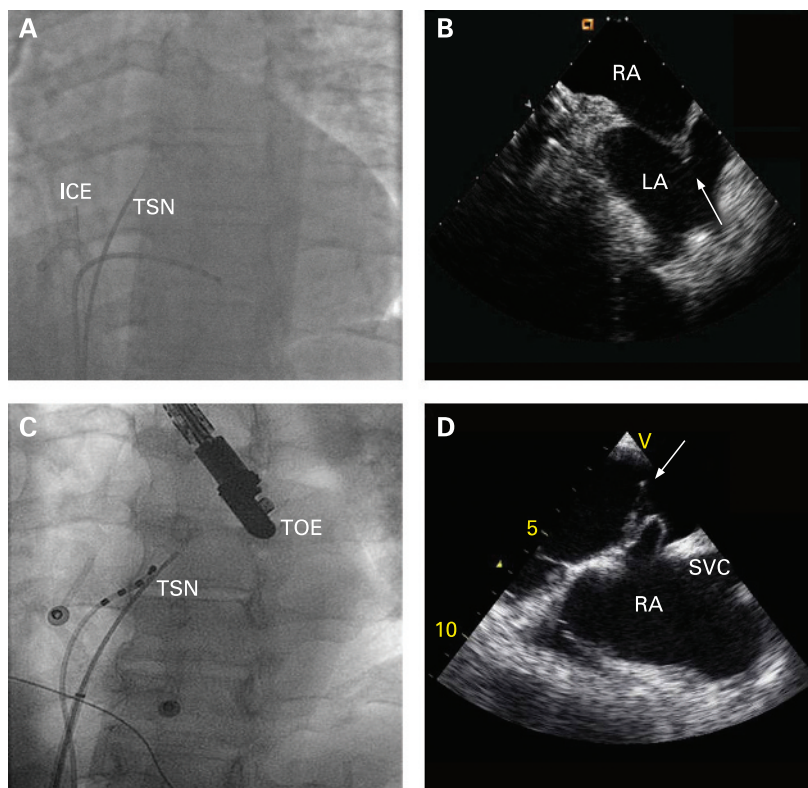


Figure 7 Echocardiographic guided transseptal puncture. (A) fluoroscopic image of the transseptal needle abutting the intra-atrial septum in the left anterior oblique (LAO) projection. A phased array transducer for intracardiac echocardiography (ICE) is positioned in the right atrium and is turned to face the intra-atrial septum. An additional quadripolar catheter is seen. (B) A corresponding ICE image with the left (LA) and right atrium (RA) marked. The white arrow indicates the transseptal needle which is tenting the fossa ovalis and prolapsing it into the LA. (C) A fluoroscopic image again in the LAO projection in which the transseptal needle is against the septum and the transoesophageal (TOE) probe is in the oesophagus. An additional quadripolar catheter is seen. (D) A corresponding TOE image with the transducer angled at 110° to give the bicaval view. The white arrow shows the needle tenting the fossa and prolapsing it into the LA. SVC, superior vena cava.

a conventional transseptal needle, to “burn” a hole through into the LA.^{19 20} This technique has not been evaluated on large numbers of patients.

Transseptal puncture in congenital heart disease

In patients with congenital heart disease who have undergone surgical or percutaneous repair, access from the RA to the LA can be required for cardiac catheterisation or intervention. To achieve this, puncture of a pericardial atrial patch or transseptal closure device may be necessary. Alternatively this may entail a “trans-baffle” puncture from the systemic to the pulmonary venous atrium following either the Mustard or Senning atrial switch procedures for transposition of the great arteries.²¹ While this can be done safely, an expert appreciation of the anatomy and surgery performed is mandatory.²² There is a significant burden of arrhythmia in these patients²³ and there are case reports of successful “left” atrial ablation via transseptal punctures through Gortex grafts and closure devices.^{21 24 25}

COMPLICATIONS

The possible complications associated with the transseptal puncture are listed in box 1 and occur in approximately 1% of procedures.⁴ In one single centre review of 1150 patients undergoing transseptal puncture for AF ablation, no failures or serious complications attributable to the puncture were reported.⁸ In a larger multicentre review of 5520 patients, 0.9% of procedures were abandoned because of inability to locate the fossa ovalis, tough atrial septum, perforation of the aortic root or most commonly perforation of the RA into the pericardial space.⁴ If this occurs a significant effusion or tamponade is unlikely, providing the sheath is not advanced creating a much larger hole in the atrial wall. For elective procedures such as AF ablation it is prudent to abandon the procedure at this stage, particularly as anticoagulation is required which could exacerbate the problem. It is worth repeating that the transseptal dilator or sheath should never be advanced unless the operator is absolutely sure the tip of needle is in the LA.

Transient ST elevation in the inferior ECG leads with or without chest pain has been reported in 0.6% of cases.⁸ It has been proposed this is a vagal response to the direct mechanical disruption of the autonomic network of the heart by the catheter during the puncture.^{26 27} An alternative explanation, however, is a coronary air embolism which may occur by not paying rigorous attention to de-airing the assembly.

The presence of a patent foramen ovale with right to left shunting is associated with stroke and migraine.²⁸ It is a concern that a persistent iatrogenic hole in the atrial septum following AF ablation may carry the same risks, although large prospective studies to measure this risk have not been done. In a study that performed a TOE 9 months post-AF ablation, eight (30%) of 27

Box 1 Complications of transseptal puncture

- ▶ Pericardial effusion or tamponade
- ▶ Aortic root needle puncture
- ▶ Right or left atrial wall needle puncture
- ▶ Pleuritic chest pain
- ▶ Stroke/transient ischaemic attack
- ▶ Transient ST elevation of inferior leads
- ▶ Persistence of atrial septal defect
- ▶ Death

patients who had two catheters through a single transseptal puncture had an iatrogenic ASD compared with none of 15 patients who had two separate punctures.⁹ In a study where TOE was performed immediately, 3, 6 and 12 months post-AF ablation using a double transseptal technique, 27 (87%) of 31 patients had an ASD immediately after ablation, but only one (3%) remained at 3 months.²⁹

CONCLUSION

The transseptal puncture is a core technique for a cardiac electrophysiologist and training should be at a centre that performs large numbers of procedures. In experienced hands it is a safe procedure; however, in institutions that perform limited numbers of cases, routine use of ICE may ensure virtually no complications.

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How to perform a transseptal puncture: key points

- ▶ The transseptal puncture is a routine procedure for cardiac electrophysiologists to access the left atrium, predominantly for ablation of atrial fibrillation.
- ▶ An intracardiac catheter should be used as an anatomical marker to avoid puncturing the aortic root.
- ▶ After the initial puncture it is essential to verify the tip of the transseptal needle is in the left atrium before advancing the dilator or sheath further.
- ▶ More than one transseptal puncture can be made to introduce multiple catheters into the left atrium.
- ▶ In view of the risk of stroke, meticulous attention to de-airing/flushing of sheaths and heparinisation is necessary.
- ▶ Approximately 1% of procedures are abandoned due to failing to cross the intra-atrial septum.
- ▶ Complications occur in 1% of patients, most commonly inadvertent puncture into the pericardial space. Tamponade is unlikely, providing the sheath/dilator are not advanced over the needle in this position.
- ▶ Real time visualisation of the intra-atrial septum may reduce this small incidence of complications even further; however, it is not routinely used due to cost constraints.
- ▶ Iatrogenic atrial septal defects have usually disappeared by 3 months.

REFERENCES

1. **Ross J Jr**, Braunwald E, Morrow AG. Left heart catheterization by the transeptal route: a description of the technique and its applications. *Circulation* 1960;**22**:927–34.
2. **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.
- ▶ **The transseptal puncture described by the group that pioneered the technique.**
3. **Mullins CE**. Transseptal left heart catheterization: experience with a new technique in 520 pediatric and adult patients. *Pediatr Cardiol* 1983;**4**:239–45.
- ▶ **This paper describes an important modification to the transseptal catheter set and is the current method widely used.**
4. **De Ponti R**, Cappato R, Curnis A, *et al*. Trans-septal catheterization in the electrophysiology laboratory: data from a multicenter survey spanning 12 years. *J Am Coll Cardiol* 2006;**47**:1037–42.
- ▶ **By far the largest observational report of patients undergoing this procedure.**
5. **Deshpande SS**, Bremner S, Sra JS, *et al*. Ablation of left free-wall accessory pathways using radiofrequency energy at the atrial insertion site: transseptal versus transaortic approach. *J Cardiovasc Electrophysiol* 1994;**5**:219–31.
6. **Katritsis D**, Giazitzoglou E, Korovesis S, *et al*. Comparison of the transseptal approach to the transaortic approach for ablation of left-sided accessory pathways in patients with Wolff-Parkinson-White syndrome. *Am J Cardiol* 2003;**91**:610–3.
7. **Lesh MD**, Van Hare GF, Scheinman MM, *et al*. Comparison of the retrograde and transseptal methods for ablation of left free wall accessory pathways. *J Am Coll Cardiol* 1993;**22**:542–9.
8. **Fagundes RL**, Mantica M, De Luca L, *et al*. Safety of single transseptal puncture for ablation of atrial fibrillation: retrospective study from a large cohort of patients. *J Cardiovasc Electrophysiol* 2007;**18**:1277–81.
- ▶ **A series of over 1000 patients describing how a single transseptal puncture can be used to introduce two sheaths into the left atrium for the purpose of ablation of atrial fibrillation.**
9. **Hammerstingl C**, Lickfett L, Jeong KM, *et al*. Persistence of iatrogenic atrial septal defect after pulmonary vein isolation – an underestimated risk? *Am Heart J* 2006;**152**:362–5.
10. **Ren JF**, Marchlinski FE, Callans DJ. Left atrial thrombus associated with ablation for atrial fibrillation: identification with intracardiac echocardiography. *J Am Coll Cardiol* 2004;**43**:1861–7.
11. **Rogers DP**, Lambiase PD, Dhinoja M, *et al*. Right atrial angiography facilitates transseptal puncture for complex ablation in patients with unusual anatomy. *J Interv Card Electrophysiol* 2006;**17**:29–34.
- ▶ **This paper describes a useful adjunctive technique in difficult cases.**
12. **Hung JS**, Fu M, Yeh KH, *et al*. Usefulness of intracardiac echocardiography in complex transseptal catheterization during percutaneous transvenous mitral commissurotomy. *Mayo Clin Proc* 1996;**71**:134–40.
13. **Wazni OM**, Beheiry S, Fahmy T, *et al*. Atrial fibrillation ablation in patients with therapeutic international normalized ratio: comparison of strategies of anticoagulation management in the periprocedural period. *Circulation* 2007;**116**:2531–4.
14. **Daoud EG**, Kalbfleisch SJ, Hummel JD. Intracardiac echocardiography to guide transseptal left heart catheterization for radiofrequency catheter ablation. *J Cardiovasc Electrophysiol* 1999;**10**:358–63.
- ▶ **An original description of intracardiac echocardiography to facilitate the transseptal puncture by one of its leading proponents.**
15. **Szili-Torok T**, Kimman G, Theuns D, *et al*. Transseptal left heart catheterisation guided by intracardiac echocardiography. *Heart* 2001;**86**:e11.
16. **Cheng A**, Calkins H. A conservative approach to performing transseptal punctures without the use of intracardiac echocardiography: stepwise approach with real-time video clips. *J Cardiovasc Electrophysiol* 2007;**18**:686–9.
17. **Haruta S**, Kouno H, Akanuma H, *et al*. The guidewire technique for transseptal puncture. *J Invasive Cardiol* 2005;**17**:68–70.
18. **Marcus GM**, Ren X, Tseng ZH, *et al*. Repeat transseptal catheterization after ablation for atrial fibrillation. *J Cardiovasc Electrophysiol* 2007;**18**:55–9.
19. **Bidart C**, Vaseghi M, Cesario DA, *et al*. Radiofrequency current delivery via transseptal needle to facilitate septal puncture. *Heart Rhythm* 2007;**4**:1573–6.

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20. **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**:327–32.

21. **Perry JC**, Boramanand NK, Ing FF. "Transseptal" technique through atrial baffles for 3-dimensional mapping and ablation of atrial tachycardia in patients with d-transposition of the great arteries. *J Interv Card Electrophysiol* 2003;**9**:365–9.
22. **El Said HG**, Ing FF, Giffka RG, *et al*. 18-year experience with transseptal procedures through baffles, conduits, and other intra-atrial patches. *Catheter Cardiovasc Interv* 2000;**50**:434–9.
23. **Abrams DJ**. Invasive electrophysiology in paediatric and congenital heart disease. *Heart* 2007;**93**:383–91.
24. **Deisenhofer I**, Estner H, Pflaumer A, *et al*. Atypical access to typical atrial flutter. *Heart Rhythm* 2005;**2**:93–6.
25. **Zaker-Shahrak R**, Fuhrer J, Meier B. Transseptal puncture for catheter ablation of atrial fibrillation after device closure of patent foramen ovale. *Catheter Cardiovasc Interv* 2008;**71**:551–2.
26. **Arita T**, Kubota S, Okamoto K. Bezold-Jarisch-like reflex during Brockenbrough's procedure for radiofrequency catheter ablation of focal left atrial fibrillation: report of two cases. *J Interv Card Electrophysiol* 2003;**8**:195–202.
27. **Letsas KP**, Pappas LK, Gavrielatos G, *et al*. ST-segment elevation induced during the transseptal procedure for radiofrequency catheter ablation of atrial fibrillation. *Int J Cardiol* 2007;**114**:e12–14.
28. **Hara H**, Virmani R, Ladić E, *et al*. Patent foramen ovale: current pathology, pathophysiology, and clinical status. *J Am Coll Cardiol* 2005;**46**:1768–76.
29. **Rillig A**, Meyerfeldt U, Birkemeyer R, *et al*. Persistent iatrogenic atrial septal defect after pulmonary vein isolation: incidence and clinical implications. *J Interv Card Electrophysiol* 2008;**22**:177–81.

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