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## 17

# Transseptal puncture

Ted Feldman and Westby G. Fisher

**Introduction • Technique • Fluoroscopic and intra-cardiac echocardiography guidance • Indications, contraindications, and complications • References**

## INTRODUCTION

The technique of transseptal puncture was developed to gain access to the left atrium (LA) for pressure measurement. Methods to measure left atrial pressure prior to the transseptal approach included direct left atrial puncture through the anterior chest wall, and trans-bronchial puncture via the left mainstem bronchus (1–8). These methods had obvious limitations. The transseptal approach was first described by Cope in 1959, using a 17-gauge solid needle introduced through polyethylene tubing via the right femoral vein (9). He employed the procedure in two patients and described left atrial and ventricular pressure measurement and angiography. In 1958 Ross et al., while working at the National Institutes of Health, were catheterizing the LA in patients with atrial septal defects. Ross was a fellow at the time. A visiting physician observed this procedure and asked whether Ross had considered using a needle to puncture the intact septum. This rapidly led to the development of a needle device for transseptal puncture via femoral cutdown in the animal laboratory (10). A few years later, when the Seldinger technique was introduced, a surgical resident working with Braunwald designed a catheter, the Brockenbrough catheter,

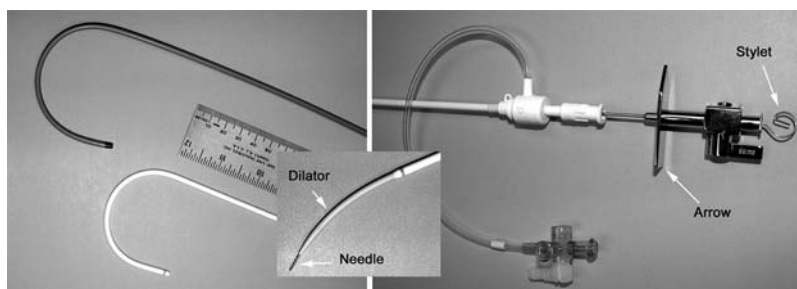
through which the Ross needle could be placed percutaneously (11–13). The substitution of the Mullins sheath for the Brockenbrough catheter was the last major advance in the basic procedure. Subsequently, the transseptal puncture procedure has undergone only minor modifications (Fig. 1) (14,15).

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Due to the technical challenges and the risks involved with transseptal puncture, pulmonary wedge pressure (PCW) measurement has been accepted as a surrogate for left atrial pressure assessment (16). PCW measurement remains the most common approach for estimation of the left atrial pressure in patients with heart failure and valvular heart disease. There are clear limitations to PCW, especially among patients with pulmonary hypertension (17–21). In the setting of pulmonary hypertension, elevated pulmonary artery pressure may “contaminate” the wedge pressure waveform and result in a significant overestimation of the PCW. Similarly, over-wedging may yield an underestimation.

Methods for retrograde catheterization of the LA via the left ventricle have been developed using specialized catheter shapes (22–24). Shirey and Sones described a multipurpose-type catheter that could be folded in the left ventricular apex and introduced into the left atrium (22). This approach is complicated by frequent

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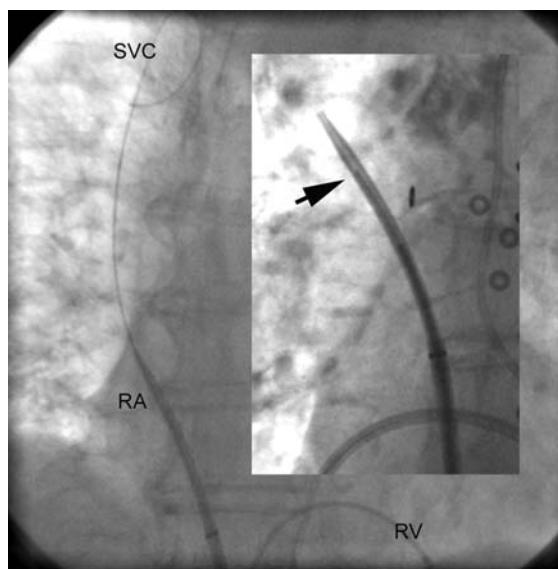
**Figure 1** Mullins sheath and transseptal needle. The left panel shows 2 brands of 8-French Mullins sheaths. The curve helps direct the tip of the sheath toward the left ventricle after placement in the left atrium. The inset shows the tip of the transseptal needle protruding from the end of the dilator-sheath assembly. The right panel shows the hub of the dilator, sheath, and needle assembly. The large metal arrow indicates the orientation of the curve of the tip of the needle. A stylet is placed within the needle as the needle is passed through the dilator initially, to keep the tip of the needle from catching or perforating the transseptal dilator and sheath during insertion of the needle.

ventricular ectopy, ventricular perforation, and inconsistent ability to cannulate the left atrium. Stefanadis et al. developed a guide catheter with a pull wire to flex the catheter tip backward from the left ventricle toward the LA, which allows introduction of a wire consistently and reliably into the left atrium (25). This device is not available in the United States and has not gained wide popularity for diagnostic purposes, being used only for retrograde, transarterial mitral balloon valvuloplasty.

Thus, transseptal puncture remains the gold standard for left atrial pressure assessment. It has clearly become more important in both electrophysiology and interventional cardiology as therapeutic procedures that require left atrial access become more common (21).

## TECHNIQUE

The basic technique involves right femoral vein access. A 0.032 in. small guide wire is passed into the superior vena cava. A pigtail catheter is placed in the aortic root to better define the location of the aortic valve. A Mullins sheath and dilator are tracked over the wire into the superior vena cava and ideally angulated toward the left subclavian vein (Fig. 2). The wire is removed. A transseptal needle is introduced into the dilator. The needle contains a stylette that keeps the tip of the needle from catching on the body of the transseptal sheath dilator as the



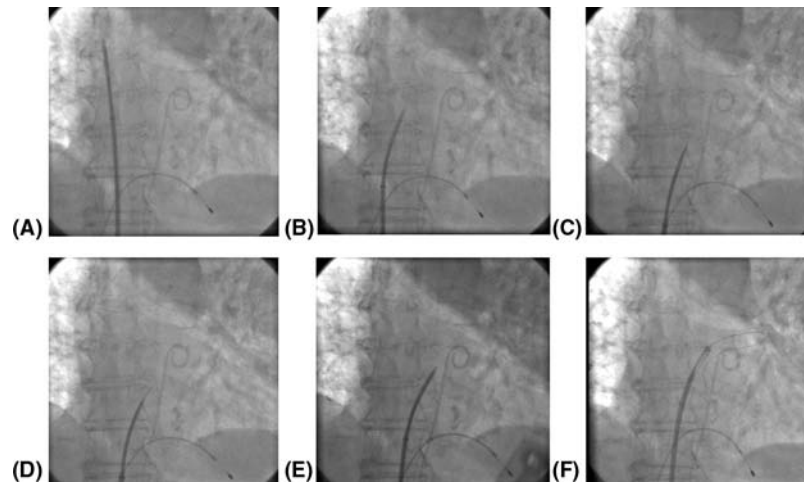
**Figure 2** The initial step in the transseptal procedure is placement of the dilator and sheath in the superior vena cava (SVC). A 0.025 in. or 0.032 in. wire is placed in the SVC. The inset shows the tip of the transseptal needle placed just within the end of the dilator (arrow). *Abbreviations:* RA, right atrium; RV, right ventricle; SVC, superior vena cava.

needle is advanced. The stylette must be withdrawn from the needle before the needle gets too close to the distal end of the transseptal dilator. The needle is positioned with its tip a few millimeters proximal to the distal end of the Mullins dilator, connected to a manifold and flushed

101 (Fig. 2, inset). Right atrial pressure is recorded  
 102 from the tip of the needle. The needle and  
 103 sheath/dilator assembly are pulled caudally  
 104 through the superior vena cava (SVC) toward  
 105 the right atrium (RA) as a unit. There is an indi-  
 106 cator arrow on the hub of the needle that shows  
 107 the direction of the angle of the needle. As the  
 108 entire apparatus is pulled inferiorly from the  
 109 SCV, the needle and Mullins sheath are rotated  
 110 as a unit clockwise until the indicator arrow  
 111 points inferiorly to between the 4 o'clock and 6  
 112 o'clock position (Fig. 3). The degree of rotation  
 113 is less in structurally normal hearts, and pro-  
 114 gressively more in aortic stenosis and mitral  
 115 valve disease. The fossa ovalis lies in the poste-  
 116 rior aspect of the intra-atrial septum and is  
 117 bounded superiorly by the limbus, an arch  
 118 shaped outer muscular rim. Classic descriptions  
 119 note two rightward movements as the needle is  
 120 withdrawn from the SVC to the RA. The needle  
 121 can be felt to move over the aortic knob, and  
 122 then drop into the fossa ovalis (Fig. 4). The first



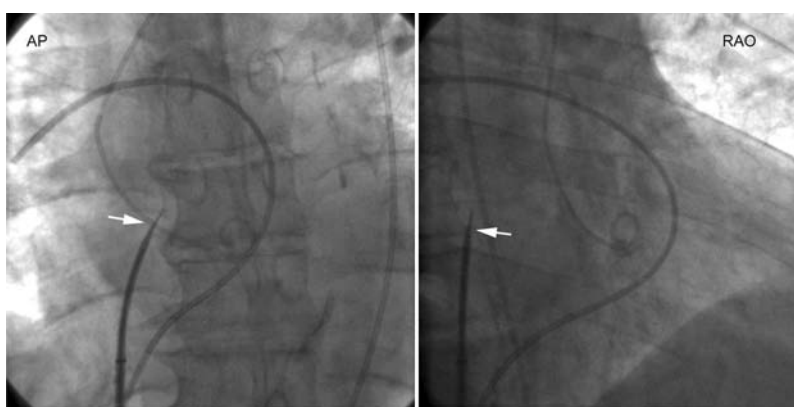
**Figure 3** The arrow indicator (*lower arrow*) on the transseptal needle is oriented toward about 4 or 5 o'clock, relative to the patient. The patient's head is on the left side of the picture, and the feet are on the right. The transseptal needle is shown attached to a manifold for pressure measurement. In the upper left corner of the picture, a second white arrow shows the right atrial pressure, displayed on the monitor.



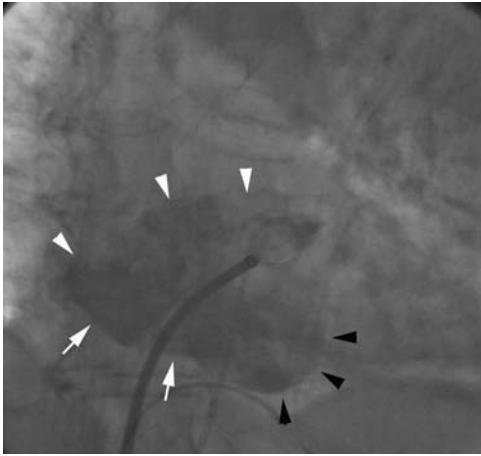
**Figure 4** The basic steps in the transseptal procedure. **(A)** The sheath, dilator, and needle have been placed in the superior vena cava. **(B)** The sheath, dilator, and needle are pulled down inferiorly as over the bulge of the aorta. **(C)** The assembly has engaged the fossa ovalis. The indicator arrow is rotated to between 4 and 6 o'clock relative to the patient. **(D)** The needle has been extended out of the dilator, through the fossa ovalis into the left atrium. Left atrial pressure should be seen on the monitor. **(E)** The dilator has been advanced over the needle into the left atrium. **(F)** A wire is advanced into the left upper lobe pulmonary vein, and the sheath advanced over the dilator. The sheath and wire are carefully removed to avoid aspiration of air, and the sheath system flushed. Heparin is administered at that point.

151 movement over the aortic knob is often difficult  
 152 to appreciate or absent. When the needle and  
 153 dilator are in place on the fossa ovalis, it usually  
 154 appears that the curve of the Mullins sheath will  
 155 directly puncture the aorta. If the image intensi-  
 156 fier is moved from an anteroposterior view to  
 157 either a right or far left anterior oblique, it is pos-  
 158 sible to see that the needle is pointing posterior  
 159 F5 to the aorta (Fig. 5). A slight forward pressure on  
 160 the needle will engage or catch on the limbus of  
 161 the fossa ovalis. In many cases, the dilator will  
 162 cross the intraatrial septum spontaneously at  
 163 that point and the left atrial pressure will be  
 164 seen. If this is not the case, pressure will damp  
 165 as the needle tip contacts the interatrial septum.  
 166 The transseptal needle is advanced out from the  
 167 tip of the transseptal dilator. The needle must be  
 168 advanced forcefully to avoid simply pushing the  
 169 fossa away in front of it. The fossa ovalis com-  
 170 prises roughly 25% to 30% of the total septal area  
 171 and is usually the thinnest portion of the  
 172 septum. The diameter of the fossa can vary dra-  
 173 matically from patient to patient. This mem-  
 174 brane consistency varies, however, usually  
 175 becoming thicker and more fibrotic with age.  
 176 The fossa may extremely thicken after prior  
 177 cardiac surgery. When the needle enters the LA,  
 178

left atrial pressure is recorded, and the dilator  
 can be advanced into the LA and the needle  
 withdrawn. Perforation of the LA posteriorly or  
 anteriorly *with the needle alone* has rarely resulted  
 in significant cardiac complications. It is typi-  
 cally the dilation with the sheath dilator or  
 sheath itself that can cause significant cardiac  
 compromise. If there is aortic or pericardial stain-  
 ing following what is presumed to be transsep-  
 tal puncture, the needle must be removed and  
 the dilator withdrawn and then the 0.032 in. J  
 wire repositioned to the SVC and the process  
 repeated. When the needle is clearly in the LA,  
 the sheath can be advanced over the dilator and  
 needle to secure access in the LA. Free back-  
 bleeding of arterial blood should be noted from  
 the hub of the Mullins dilator. Any air bubbles  
 must be aspirated. Contrast injection can be used  
 to verify the position of the Mullins sheath  
 within the LA (Fig. 6). It is useful to pass a F6  
 guidewire through the dilator just after the  
 needle has been removed to stabilize forward  
 advancement of both the dilator and the sheath.  
 One of the disappointing modes of failure for  
 this procedure is to successfully puncture the  
 septum, but then have the tip of the dilator jump  
 forward and perforate the left atrial free wall.



**Figure 5** The *left panel* shows an anteroposterior (AP) view. The *arrow* points at the tip of the dilator, from which the needle is extended into the left atrium. The *right hand panel* shows a right anterior oblique (RAO) view. The *arrow* again indicates the tip of the dilator, from which the needle extends. The pigtail catheter is resting against the aortic valve. On the AP view it appears that the needle has transected the aorta, while on the 30° right anterior oblique view it is clear that the needle overlies the spine, and is thus posterior to the aorta and pigtail.



**Figure 6** Contrast injection after successful transseptal puncture. The *white arrowheads* mark the upper border of the left atrium; the *white arrows* mark the intra-atrial septum; the *black arrowheads* show the mitral valve, closed in this angiographic frame.

Using a wire to help pass the dilator and sheath across the intra-atrial septum thus makes advancing the dilator safer. After successful puncture of the intra-atrial septum, heparin is given. The heparin dose depends on the purpose of the procedure. For a diagnostic procedure where the catheter time in the LA would be very brief, an arbitrary small dose of heparin might be used. For procedures such as valvuloplasty, activated clotting time between 200 and 300 seconds is desirable, depending on the procedure. Percutaneous mitral valve repair or longer electrophysiology procedures require activated clotting times  $\geq 300$  seconds.

The left femoral vein is usually not a successful approach, since the angulation of the left iliac vein as it joins the inferior vena cava will force the transseptal needle to move away from the intra-atrial septum. Only in patients who are very narrow hipped with a steep angle between the iliac vein and the inferior vena cava may left femoral access be likely to succeed.

Measurement of pressure through the transseptal needle is not a uniform practice. In

our opinion, it is essential for the safest method for accessing the LA. If the needle is advanced and LA pressure is not detected, a number of possibilities exist. The needle may be buried in the tissue of the septum, having taken a tangential through the septum. It is possible that the free wall of the roof of the RA or the inferior border of the RA or LA has been perforated. It is also possible that the LA has been entered, but that a small thrombus has occluded the pressure lumen of the needle. In any of these eventualities, as long as the needle is withdrawn and the 8-French sheath is not advanced, and as long as the patient is not anticoagulated, the potential for pericardial tamponade is small. As long as the incorrect position of the needle is recognized and the attempt abandoned at that point, complications from needle perforations are infrequent. This emphasizes the need to have patients off of coumadin or heparin anticoagulation prior to beginning a transseptal puncture procedure.

#### FLUOROSCOPIC AND INTRA-CARDIAC ECHOCARDIOGRAPHY GUIDANCE

Since fluoroscopy only allows indirect assessment of the location of the fossa ovalis without good visual representation of these critical anatomic landmarks, advancement of the transseptal needle using only fluoroscopically-guided techniques can be frequently associated with unpredictable outcomes. The introduction of intracardiac echocardiography has added greatly to the safety and appreciation of the anatomic variability and location of fossa ovalis. Some centers routinely perform transesophageal echocardiography to facilitate transseptal catheterization. Transesophageal echocardiography can readily image the fossa ovalis and needle assembly, but requires a second operator, greater degrees of sedation, and is not practical for long procedures. More recently, intracardiac echocardiography has been employed to facilitate transseptal catheterization. With the introduction of this technology, a single operator can perform this procedure painlessly and continuously without sedation. Intracardiac echocardiography has permitted less experienced transseptal operators to adopt the procedure.

251 The classic approach to transseptal puncture  
 252 uses fluoroscopic guidance coupled with tactile  
 253 feedback from the dilator. The location of the  
 254 puncture is "guesstimated" based on the location  
 255 of the aortic root as marked by a pigtail com-  
 256 bined with bony landmarks. The variability of  
 257 the puncture location is extreme. The classic flu-  
 258 oroscopic landmark for the puncture site is in  
 259 the center of the spine, at the level of the aortic  
 260 root. Depending on the patient's age, the relative  
 261 amounts of right and left atrial dilatation, and  
 262 spinal deformities, the puncture site may fre-  
 263 quently be to the left or right of the center of the  
 264 spine, sometimes by many centimeters. Tactile  
 265 feedback from the transseptal needle is one of  
 266 the most important descriptors of the location of  
 267 the puncture. As the dilator is withdrawn from  
 268 the SVC and felt to catch on the lumbus with a  
 269 slight forward motion, a pulsatile motion can be  
 270 felt in some cases. If fluoroscopy shows the  
 271 needle pointing posterior and away from the  
 272 aorta, the pulsatility represents the atrial "septal  
 273 bounce," whereas if the needle is pointing at the  
 274 aorta, it is the aorta that is being felt. Advance-  
 275 ment of the needle will yield a left atrial pres-  
 276 sure tracing, which confirms the left atrial  
 277 location.

278 A variety of methods can be used to determine  
 279 the location of the center of the intra-atrial  
 280 septum. One of the simplest is right atrial con-  
 281 trast injection with filming of the levo phase.  
 282 Contrast of 20 or 30 mL can be given as a bolus  
 283 in the RA. A long acquisition time is required to  
 284 be able to see the left atrial filling on the levo  
 285 phase.

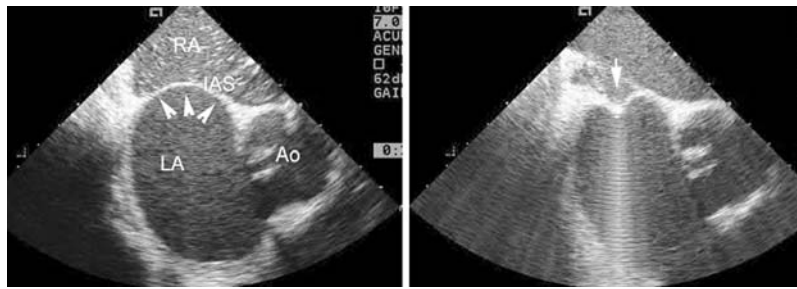
286 More recently, intravascular ultrasound has  
 287 become the method of choice to clearly visualize  
 288 the atrial septum to assist in transseptal punc-  
 289 ture (26-31). Intracardiac echo (ICE) is widely  
 290 available. A relatively simple ICE catheter is  
 291 available which uses a single rotating crystal  
 292 ultrasound transducer based on either 9-French  
 293 9 MHz rotating crystal or a 6.5-French 12.5 MHz  
 294 ultrasound crystal (CVIS<sup>®</sup>, Boston Scientific,  
 295 Sunnyvale, CA). This has the advantages of  
 296 being compatible with standard coronary  
 297 intravascular ultrasound consoles, and it is rela-  
 298 tively inexpensive, costing about the same as a  
 299 coronary IVUS catheter. It has the disadvantages  
 300 of a limited depth of field, and it provides no

more than a planar 2-dimensional view of the  
 atrial septum. Nonetheless, in many cases it is  
 adequate to demonstrate contact of the transsep-  
 tal needle with the fossa ovalis. Accuson, a 64-  
 element phased-array ultrasound system using  
 a 10-French 9 MHz transducer (AcuNav<sup>®</sup>,  
 Seimens Acuson, Mountain View, CA) that  
 images in a sector field oriented in the plane of  
 the catheter rather than a circumferential field of  
 view intracardiac echo, requires a Siemens echo  
 machine console, and the catheters are signifi-  
 cantly more expensive than the simple Boston  
 Scientific ultrasound. They have the advantage  
 of a greater depth of field, image quality that  
 appears basically equivalent to transesophageal  
 echocardiography, and the availability of color  
 Doppler as well. Accuson ICE is used widely in  
 conjunction electrophysiology ablation proce-  
 dures and with shunt closure procedures,  
 because in addition to verifying catheter place-  
 ment, it aids with device placement and assess-  
 ment of post-procedure shunting.

When the transseptal dilator engages the  
 fossa, it causes a pushing or tenting of the fossa  
 from the RA into the LA (Fig. 7). It is important **F7**  
 to note that the tip of the transseptal needle itself  
 is often echo-lucent and tenting is the only reli-  
 able sign of proper engagement of the fossa  
 ovalis. Simply seeing the echo shadow of the  
 catheter close to the septum can be highly decep-  
 tive, since the body of the transseptal catheter  
 may be transected by the plane of the ultrasound  
 beam even when the tip of the needle is far away  
 from the septum.

### The electrophysiology approach

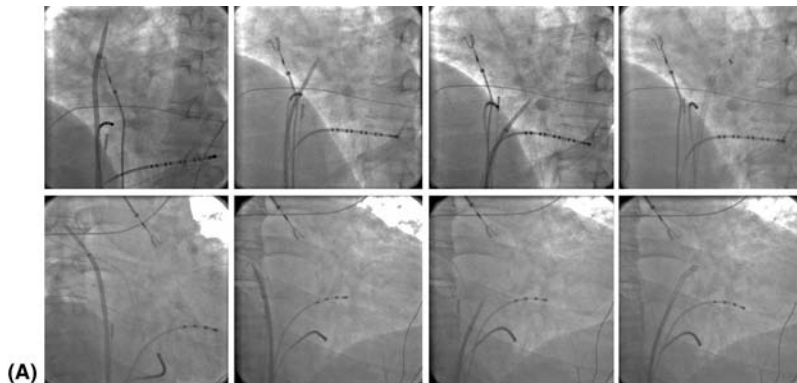
A totally venous access approach to transseptal  
 procedures is now commonly utilized in experi-  
 enced electrophysiology (EP) laboratories.  
 Because EP catheters are placed in strategic  
 anatomic locations defined by their recorded  
 electrograms, EP recording equipment is  
 required. It is our practice to begin by placing a  
 His bundle and coronary sinus catheter to  
 provide anatomic landmarks fluoroscopically  
 (Fig. 8). A His bundle catheter *that is recording a* **F8**  
*His bundle* always identifies the most inferior  
 aspect of the non-coronary cusp of the aorta.  
 This obviates the need for an arterial puncture



**Figure 7** Intracardiac echo guidance for transseptal puncture. The left panel shows a baseline image. The arrowheads show the intra-atrial septum (IAS). In the *right hand panel* the transseptal needle has been engaged in the foramen ovale; the *arrow* shows tenting of the intra-atrial septum into the LA caused by forward pressure of the transseptal dilator. There is considerable shadowing in the left atrium from the transseptal apparatus. It is notable that the needle itself is not visible, but that the tenting is well displayed. The needle is either out of plane or, because of its relatively thin structure, is in this frame echolucent. *Abbreviations:* RA, right atrium; AO, aorta; LA, left atrium.

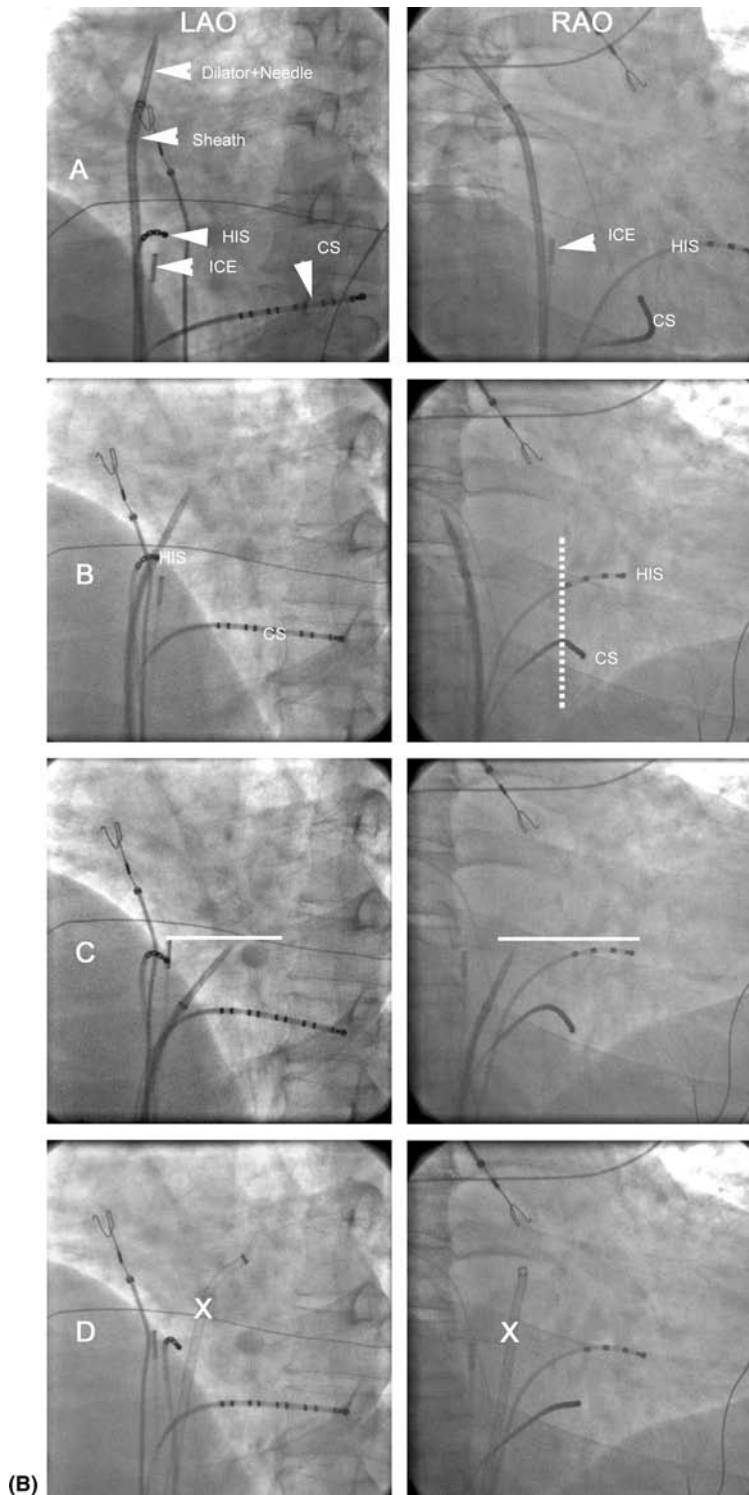
to place a pigtail catheter in the ascending aorta. A coronary sinus catheter properly placed along the artero-venous groove demarcates the widest portion of the LA parallel and just posterior to

the mitral annulus. One must ensure that the coronary sinus catheter courses near the mitral annulus by seeing equal-amplitude atrial and ventricular electrograms exist throughout the



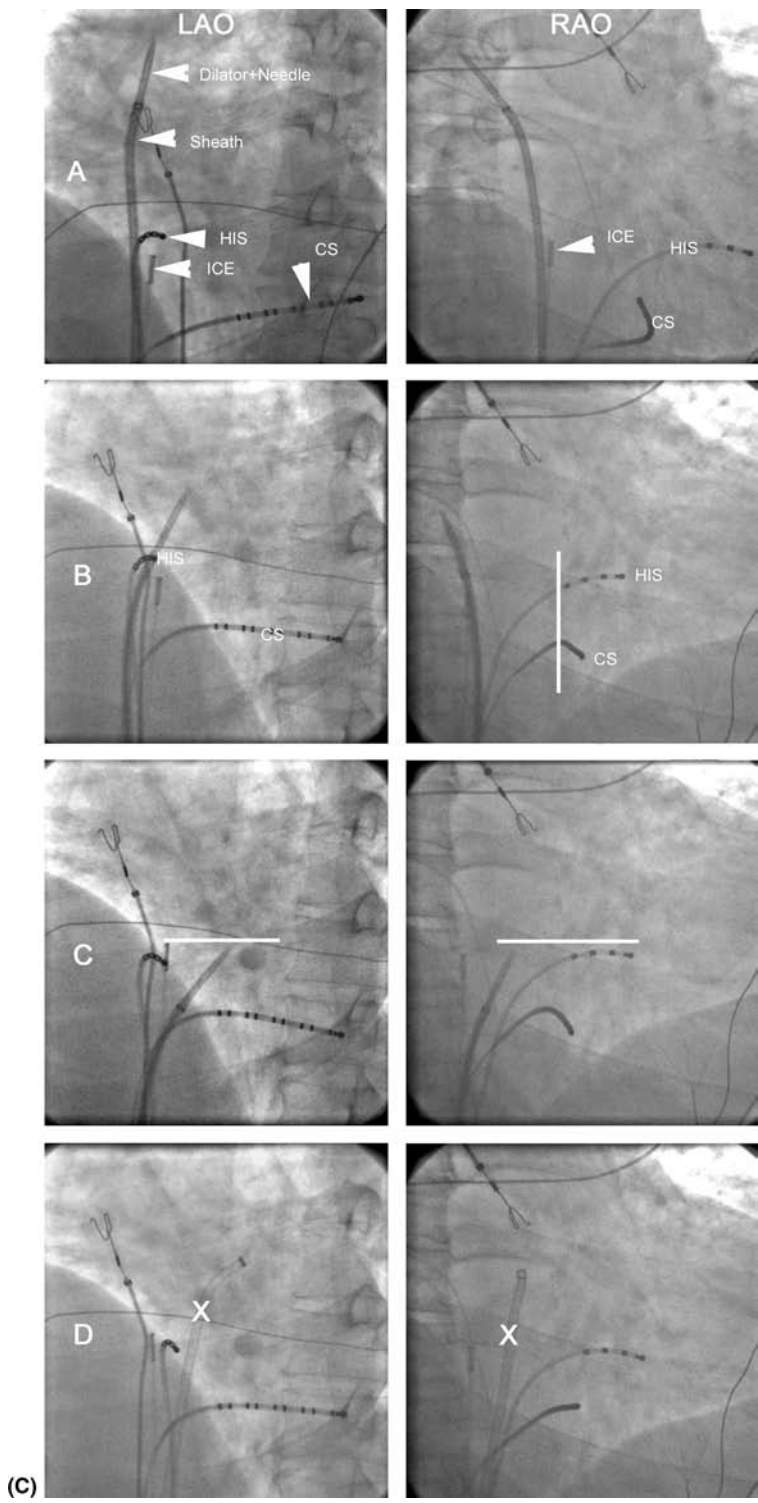
**Figure 8** (A) RAO 40 and LAO 40 fluoroscopic images of the sheath (S), dilator (D), needle (N) assembly positioned in the superior vena cava. Note the position of the His bundle catheter (His), coronary sinus catheter (CS), and intracardiac echocardiography catheter (ICE). (B) Angulation of the RAO camera is adjusted to 30 degrees so the proximal electrode of the His catheter is in the same vertical plane as the CS catheter (dashed white line in RAO view). Withdrawal of the sheath/dilator/needle (SDN) has entered the right atrium. Note the assembly is positioned too posteriorly in the RAO 30-degree view despite having the needle torqued to approximately a 4 o'clock position. (C) Proper positioning of the SDN position prior to transseptal puncture. Note the SDN assembly is oriented posterior to the His bundle catheter in the RAO view. Note that the electrograms of the His bundle must be seen to be able to use this catheter as a reliable anatomic landmark. Typically, the tip of the dilator is at the same level as the His bundle catheter (solid white line) and well to the left (posterior) of the His bundle catheter in the LAO view, and oriented posterior and parallel to the CS catheter in the RAO view. (D) Sheath position following transseptal crossing. Following transseptal puncture the dilator is advanced over the needle and dilator assembly into the left atrium. Only after the sheath is advanced into the left atrium should the needle and dilator be removed, because they provide support for the sheath to pass into the left atrium. The point of transseptal crossing is marked by an "x"

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**(B)** Figure 8 Continued.

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**Figure 8** Continued.

451 course of the catheter. If not, the catheter may  
452 have inadvertently been placed in a posterolat-  
453 eral branch of the coronary sinus and should be  
454 repositioned prior to performing transseptal  
455 catheterization.

456 The fluoroscopic views are adjusted so the His  
457 bundle catheter is pointing directly at the image  
458 intensifier of the fluoroscopic camera. The right  
459 anterior oblique angulation is adjusted so the  
460 coronary sinus catheter intersects the His bundle  
461 catheter and its midpoint. Careful evaluation of  
462 the His bundle recording should be maintained to  
463 ensure an accurate anatomic reference relative to  
464 the inferior aspect of the aorta. The transseptal  
465 needle and sheath assembly are withdrawn in the  
466 LAO view as a *single unit* maintaining the position  
467 of the needle to the dilator from the SVC position  
468 to the RA with the needle usually oriented in the  
469 4 o'clock position. If the coronary sinus catheter  
470 has been placed from a superior approach, care  
471 must be utilized to ensure that, during torquing of  
472 the sheath, the coronary sinus catheter is not  
473 twisted around the sheath and needle assembly.

474 As the needle/sheath assembly is withdrawn,  
475 an initial slight leftward jump of the assembly is  
476 noted as it enters the RA, and then a second  
477 movement leftward occurs as the catheter tip  
478 approaches the level of the His bundle catheter,  
479 which is below the superior limbus of the fossa  
480 ovalis. At this level the RAO view confirms that  
481 the catheter tip is posterior to the site of the His  
482 bundle recording and angled posterior and par-  
483 allel to the projection of the coronary sinus  
484 catheter. This angle ensures that the assembly is  
485 not pointing too posteriorly, in which case the  
486 needle may perforate the posterior wall of the  
487 LA, and not pointing too anteriorly, at which  
488 point the needle might enter the ascending  
489 aorta. Adjustments of angulation between 3  
490 o'clock and 6 o'clock may be necessary, with  
491 enlarged left atria often requiring a more poste-  
492 rior (or 5 to 6 o'clock) angulation and vertically  
493 oriented hearts requiring a more anterior (3 to 4  
494 o'clock) angulation of the needle.

495 When the angulation of the needle is con-  
496 firmed, transseptal crossing is done in the LAO  
497 projection. The assembly is withdrawn. 25–.5 cm  
498 farther and then advanced to engage the limbus  
499 of the fossa ovalis. Patients with patent foramen  
500 ovale will have the dilator move toward the left

atrium. If hemodynamics are utilized, the left  
atrial pressure recording can be recorded from  
the transseptal needle or the needle location can  
be confirmed by ICE or contrast injection. More  
commonly, however, the dilator does not pass  
spontaneously into the left atrium. Pressure  
measurements are usually damped when the  
needle and dilator are juxtaposed to the intra-  
atrial septum. When the transseptal needle is  
advanced to enter the LA, a tactile “pop” is felt.  
This can be confirmed by contrast injection or  
pressure recording from the tip of the needle.  
The dilator is then advanced over the needle  
assembly to enter the LA and, with the support  
of the needle, the sheath is advanced over the  
dilator into the LA. If there is any question about  
the location of the needle the dilator should not  
be advanced. Once the sheath is in the LA and  
has been flushed, heparin is given.

### Thickened atrial septum

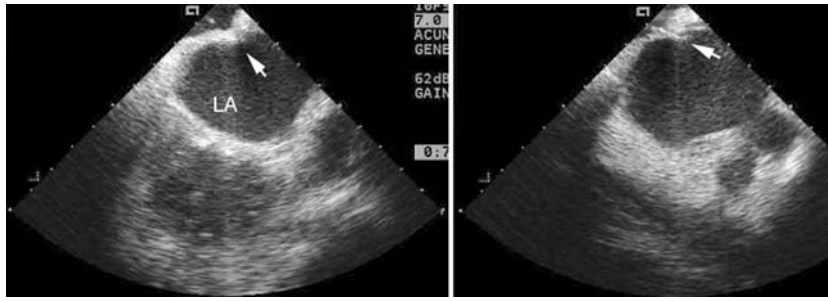
A septum thick enough to make puncture difficult  
may be encountered in older patients with lipom-  
atous hypertrophy and after prior open heart  
surgery (31–36). Patients with prior valve surgery  
may develop endocardial thickening, and in some  
cases the fossa is sutured to prevent air embolism.  
Puncture may also be performed after atrial septal  
patching or repair for congenital heart disease. In  
all of these situations ICE is extremely helpful and  
puncture is often unsuccessful without ICE guid-  
ance (Fig. 9). The needle may be advanced tan- F9  
gentially into the septal tissue, so that even if the  
puncture location is correct, it is not possible to  
reach the LA. When the transseptal needle causes  
“tenting” of the septum, more force than is  
otherwise acceptable can be used to advance into  
the LA. Another method to cross a tough or thick  
septum is with radiofrequency perforation (37).  
This requires specialized equipment, and is best  
performed with ICE.

### Indications, contraindications, and complications

#### Indications

Indications for transseptal procedures include a  
variety of diagnostic uses, and an increasing

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511 **Figure 9** Intracardiac echo images from a patient with a markedly thickened intra-atrial septum. This  
512 patient had undergone prior resection of a right atrial myxoma from the right atrial free wall. The septum is  
513 almost 1-cm thick. The *left panel* shows tenting of the septum from a transseptal dilator marked by the  
514 *arrow*. With full extension of the needle, the left atrium could not adequately be entered. Forward pressure  
515 on the needle, more extreme than would be possible without echo guidance, was necessary to force the  
516 needle into the left atrium, and ultimately record left atrial pressure via the needle before advancing the  
517 dilator. The *right panel* shows the needle across the septum, markedly by the *arrowhead*. *Abbreviation:* LA,  
518 left atrium.

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521 array of therapeutic procedures (35–39).  
522 Diagnostic assessment of mitral and aortic valve  
523 disease, congenital lesions, and hypertrophic  
524 cardiomyopathy are the most frequent situations  
525 in which transseptal puncture is employed.  
526 Mitral stenosis is, of course, the most classic, and  
527 catheter-based mitral valve repair the most  
528 recent (39). Direct measurement of left atrial  
529 pressure combined with retrograde left ventric-  
530 ular pressure yields accurate assessment of the  
531 transmitral pressure gradient. It is also possible  
532 to pass a French Mullins sheath into the LA, and  
533 through this float a 7-French balloon tip catheter  
534 F10 into the left ventricle (Fig. 10). Thus simultane-  
535 ous left atrial and left ventricular pressure can  
536 be obtained via a single venous puncture  
537 without the need for arterial catheterization or  
538 retrograde crossing of the aortic valve. Similarly,  
539 this approach for left ventricular pressure mea-  
540 surement can be coupled with retrograde place-  
541 ment of a catheter in the central aorta for  
542 accurate assessment of the transaortic valve  
543 pressure gradient in aortic stenosis or hyper-  
544 trophic cardiomyopathy. This method yields  
545 pressures recorded directly from either side of  
546 the valve and avoids all of the artifacts of pres-  
547 sure amplification and damping that are  
548 common in peripheral arterial sheath substitu-  
549 tion for the central aortic pressure when assess-  
550 ing aortic valve stenosis.

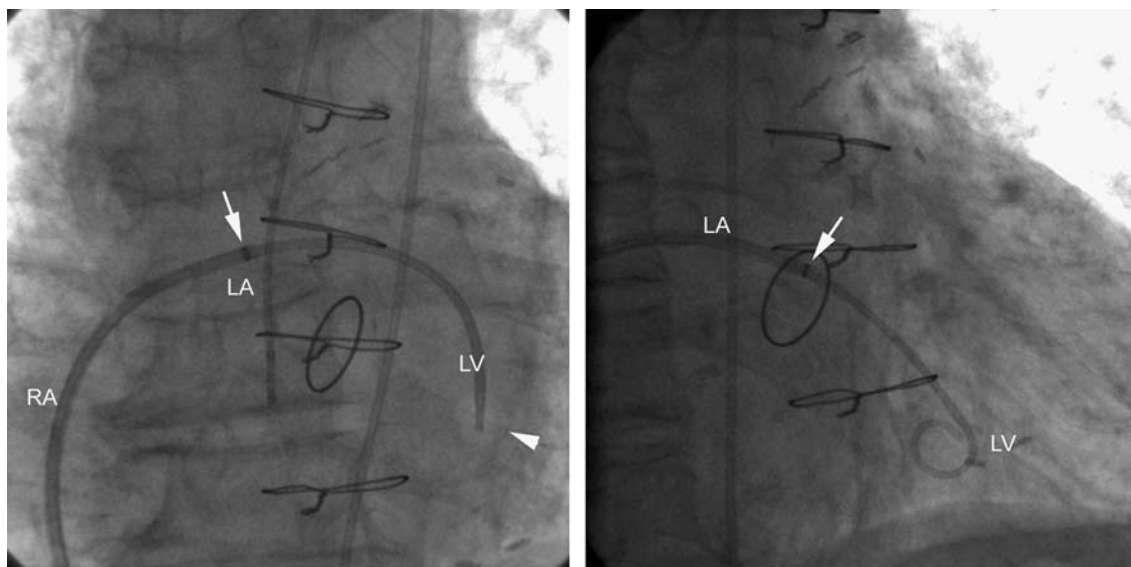
In rare instances, the transseptal approach has  
been used to pass a catheter into the aortic root  
for coronary arteriography. This can be accom-  
plished in patients with limited access from the  
extremities. It, of course, requires a great deal of  
catheter manipulation and time to achieve selec-  
tive or semiselective coronary arteriography.

The method for access of the aorta via the  
transseptal route is used increasingly for thera-  
peutic procedures but also has diagnostic utility.  
A 8-French transseptal sheath is placed in the  
LA. A 7-French balloon catheter is floated into  
the left ventricle. The catheter can be curved in  
the left ventricular apex, or a curved wire can be  
introduced into the catheter to help it make the  
turn around the apex, and then the balloon  
catheter is floated across the aortic valve into the  
aortic root. This allows measurement sequen-  
tially of the entire right and left heart circula-  
tions, or passage of a guidewire from the RA,  
across the septum into the LA, through the left  
ventricle, into the aorta, and sometimes out  
through a femoral arterial sheath. This trans-  
circulatory wire loop is sometimes called “floss-  
ing” the circulation (Fig. 11) (21,36).

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Therapeutic uses for transseptal catheterization  
are increasing rapidly. Catheter ablation for left  
sided accessory pathways and atrial fibrillation in  
electrophysiology have become common proce-  
dures. Antegrade valvuloplasty of the mitral

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**Figure 10** Catheterization of the left ventricle via the mitral valve after transseptal puncture. This is an excellent method to record a transaortic or transmitral valve pressure gradient. In this case, the patient has a Hancock bioprosthetic aortic valve replacement. A pigtail catheter sits in the sinus of Valsalva adjacent to the valve in the *left panel* (AP view). The *arrow* marks the tip of the Mullins sheath. A 7-French single lumen balloon catheter has been floated across the mitral valve into the left ventricle. The inflated balloon is marked by the *arrowhead*. In the *right hand panel* in a right anterior oblique view, a pigtail catheter has been substituted for the single lumen balloon catheter for ventriculography. Simultaneous recording of the left atrial and left ventricular pressures for evaluation of mitral stenosis, and of the left ventricular and aortic pressures for evaluation of the transaortic valve pressure gradient can be easily accomplished. A central aortic pigtail catheter is just visible in the upper left corner of this frame. *Abbreviations:* RA, right atrium; LA, Left atrium; LV, left ventricle.

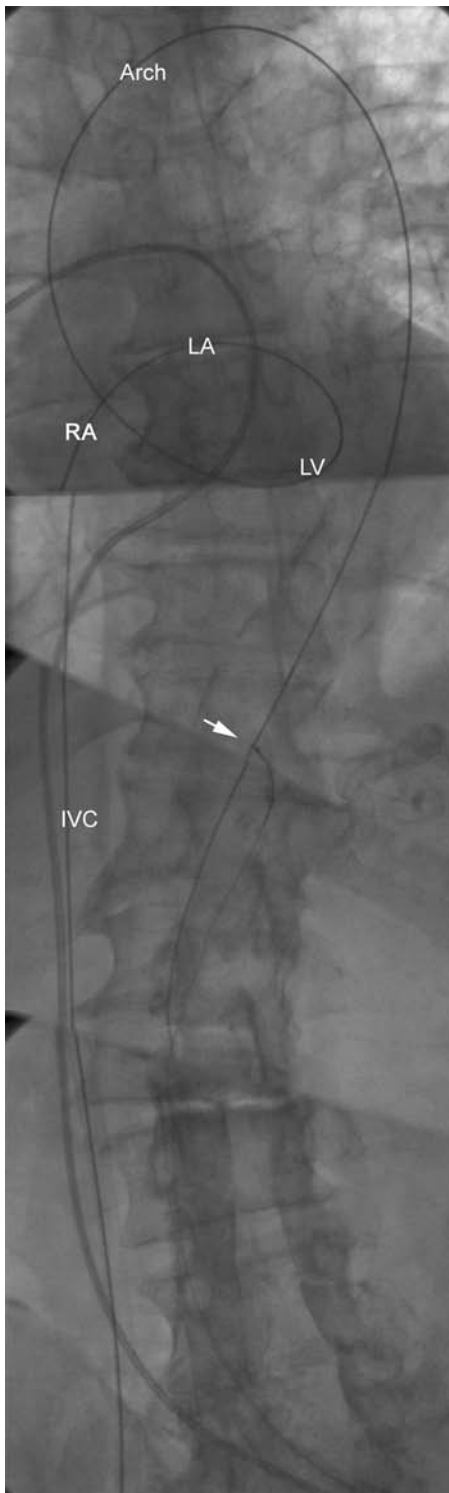
valve, and also of the aortic valve is accomplished using transseptal access. Paravalvular leak closure also frequently requires transseptal access either for delivery of a closure device, or for wire passage to ultimately allow retrograde delivery catheter placement. The variety of new percutaneous valve repair and replacement therapies require transseptal puncture as well. Mitral valve repair is predicated on left atrial access via the transseptal route. The E-valve procedure uses a 24-French venous cannula to access the LA, and then place a clip directly on the mitral leaflets. A great advantage of the transseptal route is the ability to place large catheters in the femoral vein, and then achieve left heart access. The obviates the need for large bore atrial sheaths in many instances. Antegrade aortic balloon valvuloplasty is accomplished using a 14-French venous sheath. This bears the challenges of arterial access and

hemostasis using sheaths of that caliber via the arterial route, necessary of course for retrograde aortic valvuloplasty.

### Contraindications

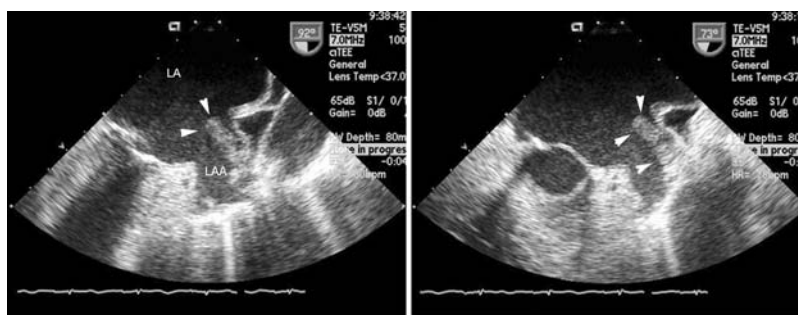
The most important contraindications to transseptal puncture include atrial thrombus or mass. Right atrial thrombus may form on pacemaker leads or inferior vena cava filters. It is unusual for right atrial thrombus to directly preclude transseptal puncture. Left atrial appendage thrombus is a more common problem (Fig. 12). In mitral stenosis patients who have not been on coumadin, left atrial appendage thrombi will often resolve in 2 to 4 months with coumadin therapy. For patients who have been on coumadin, the addition of antiplatelet therapy and more intense coumadin therapy is sometimes

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**Figure 11** A guidewire has been placed via the transseptal route throughout the whole circulation. This is sometimes called “flossing” the circulation. The course of the wire involves introduction through a transseptal sheath via the inferior vena cava (IVC), right atrium (RA), left atrium (LA), across the mitral valve and into the left ventricle (LV), then out into the aortic arch and the descending aorta. In this example the wire has been snared in the descending aorta (*arrow*). The snare has been closed on the wire to provide stability for antegrade aortic balloon valvuloplasty. It is also possible to snare the wire and exteriorize it, which allows introduction of devices from either the arterial or venous limbs of the same wire. Importantly, when a wire loop like this is removed from the circulation it is critical to cover it with a diagnostic catheter so that friction of the wire does not lacerate the heart valves.

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**Figure 12** Transesophageal echocardiographic images showing left atrial thrombus. Atrial appendage thrombus is one of the most important contraindications to transseptal procedures. On the *left panel*, the arrowhead show a large thrombus. On the *right panel* in a second frame, the thrombus is seen to have a lobular or globular appearance. The thrombus extends out of the left atrial appendage (LAA) into the body of the left atrium (LA). Echocardiographic smoke is seen in the appendage and extending out into the body of the left atrium.

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successful. Smoke, or spontaneous echo contrast, in the LA is not a contraindication to transseptal puncture. Rare cases of atrial septal thrombus are encountered and represent an important contraindication to transseptal puncture. In cases where left atrial appendage thrombus is seen on a baseline echo, and then appears in a stable concave, echo-dense (organized) configuration on a follow-up echo after prolonged anticoagulation therapy, it is sometimes safe to proceed with transseptal puncture. If the atrial appendage thrombus is well organized, there is little risk of embolization. Unfortunately it is prospectively very difficult to tell whether any fresh or mobile thrombus might exist on the surface of an echo-dense organized thrombus. Thus, left atrial appendage thrombus remains an important relative contraindication to this procedure.

Another strong relative contraindication to transseptal puncture is in patients who have abnormal coagulation or thrombocytopenia. Many patients present for transseptal catheterization having been on coumadin. Coumadin is typically discontinued 3 or 4 days before the catheterization procedure. A bridge using heparin or Lovenox<sup>®</sup> (Aventis, Bridgewater, NJ) is commonly employed. It is my practice to proceed with transseptal puncture only if the international normalized ratio (INR) is less than or equal to 1.7. After a hiatus off of coumadin therapy, patients will occasionally appear with an elevated INR and the procedure must be

delayed. Platelet counts of 50,000 to 100,000 represent a degree of thrombocytopenia that imposes an important risk for tamponade if an errant puncture results from the procedure. A platelet count over 100,000 can generally be regarded as acceptable for proceeding with a transseptal puncture.

### Complications

Thromboemboli from the catheter, needle, or cardiac chambers may occur. Extreme care to flush and wipe the transseptal system frequently is needed to avoid thrombus formation on the transseptal needle. The stainless steel needle is metal and highly thrombogenic. In most reported series cardiac tamponade occurs in 0.5–2%, and stroke in <1% (41). Both cardiac perforation and thromboembolism can be fatal.

The vast majority of complications that arise from transseptal catheterization occur from inadvertent puncture of adjacent structures to the interatrial septum and fossa ovalis. Thus, anticoagulation is not given until the LA has been safely entered. The interatrial septum is bounded posteriorly by the pericardium. The aortic root lies superior and anterior to the fossa ovalis while the coronary sinus ostium lies inferior to the fossa ovalis and posterior to the tricuspid valve orifice. In pathologic hearts there is frequent distortion of the atrial and interatrial septum anatomy, which can significantly alter the proximity of these structures. The septum

701 tends to lie more horizontal in patients with left  
702 atrial enlargement and can be more vertical in  
703 patients with aortic valve disease or a dilated  
704 aortic root. Varying degrees of kyphoscoliosis  
705 can also alter intrathoracic cardiac rotation. Also,  
706 prior open heart surgery can result in a thick-  
707 ened fossa ovalis because surgeons occasionally  
708 must over-sew the fossa in patients with a patent  
709 foramen ovale to ensure evacuation of air from  
710 the LA before coming off cardiopulmonary  
711 bypass. Cardiac perforation may result from  
712 perforation of the RA, perforation of the LA after  
713 successful transseptal puncture, and also by per-  
714 foration through the inferior border of the RA  
715 across the transverse pericardial sinus and then  
716 into the LA. This latter route for perforation may  
717 not be recognized until the conclusion of the  
718 procedure, since the catheter will exit the RA and  
719 very quickly enter the LA, yielding a good left  
720 atrial pressure wave form. It is not until the  
721 catheter is removed that the puncture through  
722 the space between the RA and LA at the lower  
723 border can be recognized. After balloon mitral  
724 valvotomy procedures, it is my practice to leave  
725 the wire across the transseptal puncture after the  
726 catheters have been removed for about 5  
727 minutes with continuous arterial pressure mon-  
728 itoring. This allows re-access to the puncture site  
729 and LA if a puncture across the transverse peri-  
730 cardial sinus has occurred.

731 The performance of transseptal puncture  
732 cannot reasonably be undertaken without readi-  
733 ness also to perform pericardiocentesis (42).  
734 When hypotension occurs during a transseptal  
735 procedure, it is fair to assume that it is due to  
736 cardiac perforation until proven otherwise.  
737 Pleuritic chest pain, shoulder pain, or new atrial  
738 fibrillation should also raise suspicion regarding  
739 potential perforation. The ready availability of  
740 echocardiography to help with both the confir-  
741 mation of the diagnosis and the performance of  
742 pericardiocentesis is helpful. In the event that  
743 pericardiocentesis is necessary, it can almost  
744 always be accomplished using equipment  
745 already available on the catheterization table  
746 without a special pericardiocentesis set. A stan-  
747 dard 18-gauge thin wall needle is adequate to  
748 reach the pericardial space in the vast majority  
749 of patients. While the traditional approach for  
750 pericardiocentesis involves directing the needle

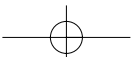
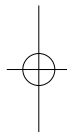
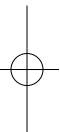
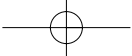
from the left subxiphoid angle toward the left  
shoulder, in the setting of acute pericardial tam-  
ponade, it is common for the effusions to be  
much smaller and a more vertical pathway is  
needed to reach the pericardial space. It is my  
usual practice when echocardiographic guid-  
ance is not available, to make a first pass with  
the needle angulated toward the mid part of the  
left clavicle. A standard pigtail catheter of any  
French size can be used for initial pericardial  
drainage. Once the blood pressure is stabilized,  
the pigtail catheter can be exchanged for a  
multihole pericardial drainage catheter. Gener-  
ally, the drain should be left overnight, since  
continued bleeding from a perforation may  
occur. It is disappointing to create a perforation  
during a transseptal procedure, successfully  
drain the pericardium, and then have the patient  
tamponade some hours later from recurrent  
bleeding if the drain has been removed prema-  
turely. The drain can be discontinued when there  
is less than 100 mL of drainage in a 24-hour  
period.

If perforation is recognized after administra-  
tion of heparin, protamine should be used to  
reverse the anticoagulation. Protamine sulfate is  
itself a mild anticoagulant, but when given with  
heparin (which is strongly acidic) a stable, non-  
coagulating salt is created and inactivates the  
anticoagulant effect of heparin. On average 1 mg  
of protamine will reverse approximately 90 USP  
units heparin derived from beef lung or 115 USP  
units of heparin derived from porcine intestinal  
mucosa. Usually it is advised that no more than  
50 mg of protamine be given over 10 minutes.  
Rapid administration of protamine can result in  
severe hypotension, anaphylactoid reactions,  
and respiratory compromise. In practice, admin-  
istration of 5–10 mg of protamine at one time  
with frequent reassessment of the ACT will  
achieve reversal of anticoagulation with a  
minimum of complications. Typically no more  
than 100 mg of protamine should be adminis-  
tered acutely. Because protamine sulfate can  
cause anaphylaxis, medications should also be  
available to deal with this emergency as well.  
Anaphylactoid reactions are more common in  
diabetic patients who have taken NPH insulin,  
which contains protamine and sensitizes some  
of them to protamine.

## REFERENCES

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1. Facquet J, Lemoine J, Alhomme P, Lefeboie J. La mesure de la pression auriculaire gauche par voie transbronchique. *Arch Mal Coeur* 1952; 8:741.
  2. Aluson PR, Linden RJ. The bronchoscopic measurement of left auricular pressure. *Circulation* 1953; 7:669.
  3. Bjork VO, Malmstrom G, Uoola LG. Left auricular pressure measurements in man. *Ann Surg* 1953; 138:718.
  4. Radner S. Suprasternal puncture of the left atrium for flow studies. *Acta Med Scandinav* 1954; 148:57.
  5. Brock R, Milstein BB, Ross DH. Percutaneous left ventricular puncture in the assessment of aortic stenosis. *Thorax* 1956; 11:163.
  6. Lehman JS, Musser BG, Lykens HD. Cardiac ventriculography: Direct transthoracic needle puncture opacification of the left (or right) ventricle. *Am J Roentgenol* 1957; 77:207.
  7. Levy MJ, Amplatz K, Lillehei CW. Transthoracic left heart catheterization and angiocardiology for combined assessment of mitral and aortic valves. *Radiology* 1962; 78:638.
  8. Levy MJ, Lillehei CW. Percutaneous direct catheterization—a new method, with results in 122 patients. *New England J Med* 1964; 271:273.
  9. Cope C. Technique for the transseptal catheterization of the left atrium: preliminary report. *J Thorac Surg* 1959; 37:482–486.
  10. Ross J, Braunwald E, Morrow AG. Transseptal left atrial puncture: new technique for the measurement of left atrial pressures. *Am J Cardiol* 1959; 3:653–655.
  11. Brockenbrough EC, Braunwald E, Ross J Jr. Transseptal left heart catheterization: a review of 450 studies and description of an improved technique. *Circulation* 1962; 25:15–21.
  12. Ross J Jr. Considerations regarding the technique for transseptal left heart catheterization. *Circulation* 1966; 34(3):391–399.
  13. Braunwald E. Transseptal left heart catheterization. *Circulation* 1968; 37(suppl 3):74–79.
  14. Laskey WK, Kusiak V, Untereker WJ, Hirshfeld JW Jr. Transseptal left heart catheterization: utility of a sheath technique. *Catheter Cardiovasc Diagn* 1982; 8(5):535–542.
  15. Mullins CE. Transseptal left heart catheterization: Experience with a new technique in 520 pediatric and adult patients. *Pediatr Cardiol* 1983; 4:239–245.
  16. Swan HJ, Ganz W, Forrester J, Marcus H, Diamond G, Chonette D. Catheterization of the heart in man with use of a flow directed balloon-tipped catheter. *N Engl J Med* 1970; 283:447–451.
  17. Schoenfeld MH, Palacios IF, Hutter AM Jr, Jacoby SS, Block PC. Underestimation of prosthetic mitral valve areas: role of transseptal catheterization in avoiding unnecessary repeat mitral valve surgery. *J Am Coll Cardiol* 1985; 5(6):1387–1392.
  18. Marzocchi A, Piovaccari G, Zimarino M, Branzi A, Magnani B. Adjustment of pulmonary capillary wedge pressure for wave delay increases the accuracy of mitral valve area measurement. *J Heart Valve Dis* 1995; 4(3):242–246.
  19. Haskell RJ, French WJ. Accuracy of left atrial and pulmonary artery wedge pressure in pure mitral regurgitation in predicting left ventricular end-diastolic pressure. *Am J Cardiol* 1988; 61(1):136–141.
  20. Kane PB, Askanazi J, Neville JF Jr, Mon RL, Hanson EL, Webb WR. Artifacts in the measurement of pulmonary artery wedge pressure. *Crit Care Med* 1978; 6(1):36–38.
  21. Syed Z, Salinger MH, Feldman T. Alterations in left atrial pressure and compliance during balloon mitral valvuloplasty. *Catheter Cardiovasc Interv* 2004; 61:571–579.
  22. Shirey EK, Sones FM Jr. Retrograde transaortic and mitral valve catheterization. Physiologic and morphologic evaluation of aortic and mitral valve lesions. *Am J Cardiol* 1966; 18(5):745–753.
  23. Freeman DJ. New performed catheter and method for retrograde left atrial or complete left heart catheterization. *Catheter Cardiovasc Diagn* 1978; 4(3):305–310.
  24. Freeman DJ. New family of preformed left atrial-coronary catheters for retrograde left atrial catheterization and coronary and/or aortocoronary bypass angiography via brachial artery cutdown. *Catheter Cardiovasc Diagn* 1981; 7(3):321–326.
  25. Stefanadis CI, Stratos CG, Lambrou SG, et al. Retrograde nontransseptal balloon mitral valvuloplasty: immediate results and intermediate long-term outcome in 441 cases—a multicenter experience. *J Am Coll Cardiol* 1998; 32(4):1009–1016.
  26. Hung JS, Fu M, Yeh KH, Wu CJ, Wong P. Usefulness of intracardiac echocardiography in complex transseptal catheterization during percutaneous

- 801 transvenous commisurotomy. *Mayo Clin Proc*  
802 1996; 71:134–140.
- 803 27. Daoud EG, Kalbfleisch SJ, Hummel JD. Intracar-  
804 diac echocardiography to guide transseptal  
805 catheterization for radiofrequency catheter abla-  
806 tion. *J Cardiovasc Electrophysiol* 1999; 10: 358–363.
- 807 28. Epstein LM, Smith T, TenHoff H. Nonfluoroscopic  
808 transseptal catheterization: safety and efficacy of  
809 intracardiac echocardiographic guidance. *J Car-  
810 diovasc Electrophys* 1998; 9:625–630.
- 811 29. Sethi KK, Mohan JC. Transseptal catheterization  
812 for the electrophysiologist: modification with a  
813 “view”. *J Intervent Card Electrophys* 2001; 5:  
814 97–99.
- 815 30. Gonzalez MD, Otomo K, Shah N, et al. Transsep-  
816 tal left heart catheterization for cardiac ablation  
817 procedures. *J Interv Cardiac Electrophys* 2001; 5:  
818 89–95.
- 819 31. Green NE, Hansgen AR, Carroll JD. Initial clini-  
820 cal experience with intracardiac echocardiogra-  
821 phy in guiding balloon mitral valvuloplasty:  
822 technique, safety, utility, and limitations. *Catheter*  
823 *Cardiovasc Interv* 2004; 63(3):385–394.
- 824 32. El-Said HG, Ing FF, Grifka RG, et al. 18-year  
825 Experience with transseptal procedures  
826 through baffles, conduits, and other intra-atrial  
827 patches. *Catheter Cardiovasc Interv* 2000; 50:  
828 434–439.
- 829 33. Koenig P, Hijazi ZM. Transseptal puncture  
830 through an artificial material: a safe technique.  
831 *Catheter Cardiovasc Interv* 2000; 50:440.
- 832 34. Schneider MBE, Zartner PA, Magee AG.  
833 Transseptal approach in children after patch  
834 occlusion of atrial septal defect: first experience  
835 with cutting balloon. *Catheter Cardiovasc Interv*  
836 1999; 48:378–381.
- 837  
838  
839  
840  
841  
842  
843  
844  
845  
846  
847  
848  
849  
850
35. Sakata Y, Feldman T. Transcatheter creation of  
atrial septal perforation using radio frequency  
transseptal system: novel approach as an alter-  
native to transseptal needle puncture. *Catheter*  
*Cardiovasc Interv* 2005; 64:327–332.
36. Feldman T. Transseptal antegrade access for  
aortic valvuloplasty. *Catheter Cardiovasc Inter-  
vent* 2000; 50:492–494.
37. Sakata Y, Sayed Y, Salinger MH, Feldman T. Per-  
cutaneous balloon aortic valvuloplasty: ante-  
grade transseptal vs. conventional retrograde  
transarterial approach. *Catheter Cardiovasc*  
*Interv* 2005; 64:314–321.
38. Feldman T, Herrmann HC, Inoue K. The tech-  
nique of percutaneous transvenous mitral  
commisurotomy using the Inoue balloon  
catheter. *Catheter Cardiovasc Diagn* 1994; (supp  
2):26–34.
39. Feldman T. Core Curriculum for interventional  
cardiology: Percutaneous valvuloplasty. *Catheter*  
*Cardiovasc Interv* 2003; 60:48–56.
40. Feldman T, Wasserman HS, Herrmann HC, et al.  
Percutaneous mitral valve repair using the edge-  
to-edge technique: 6 month results of the  
EVEREST Phase I Clinical Trial. *J Am Coll Cardiol*  
2005; 46:2134–2140.
41. Roelke M, Smith AJ, Palacios IF. The technique  
and safety of transseptal left heart catheteriza-  
tion: the Massachusetts General Hospital experi-  
ence with 1,279 procedures. *Catheter Cardiovasc*  
*Diagn* 1994; 32(4):332–339.
42. Feldman T, Sandborn T, Ziskind AA, Kern MJ.  
Pericardiocentesis, balloon pericardiotomy and  
special techniques. In: Kern MJ, ed. *Interven-  
tional Cardiac Catheterization Handbook*. 2nd  
ed. Mosby-Year Book, 2004:481–499.



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