

Atrial Septal Puncture Technique in Percutaneous Transvenous Mitral Commissurotomy: Mitral Valvuloplasty Using the Inoue Balloon Catheter Technique

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Transseptal catheterization is a vital component of percutaneous transvenous mitral commissurotomy. Therefore, a well-executed transseptal catheterization is the key to a safe and successful percutaneous transvenous mitral commissurotomy. Two major problems inherent in atrial septal puncture for percutaneous transvenous mitral commissurotomy are cardiac perforation and puncture of an inappropriate atrial septal site. The former may lead to serious complication of cardiac tamponade and the latter to possible difficulty in maneuvering the Inoue balloon catheter across the mitral orifice. This article details atrial septal puncture technique, including landmark selection for optimal septal puncture sites, avoidance of inappropriate puncture sites, and step-by-step description of atrial septal puncture.

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INTRODUCTION

Transseptal catheterization, originally developed by Cope [1] and by Ross [2] in 1959, is an established diagnostic technique for obtaining accurate left heart hemodynamic and angiographic information. In recent years its utility as a diagnostic tool has decreased markedly and the technique has been questioned as losing skills [3]. Since the introduction of catheter balloon percutaneous transvenous mitral commissurotomy (PTMC) for treatment of mitral stenosis by Inoue et al. in 1984 [4], transseptal catheterization has regained its importance, now as a vital component of this therapeutic intervention technique. Increasing use of transseptal catheterization is expected as extensive clinical experience has established the effectiveness and safety of PTMC [5-10], and its long-term follow-up results are encouraging [7,8,10].

Two major problems inherent in atrial septal puncture for PTMC are cardiac perforation and puncture of an inappropriate atrial septal site. The former may lead to serious complication of cardiac tamponade and the latter to possible difficulty in maneuvering the Inoue balloon catheter across the mitral orifice [10]. Therefore, a well-executed transseptal catheterization is the key to a safe and successful PTMC. The transseptal puncture technique for diagnostic left heart catheterization has been extensively described [1-3,11-24]. However, in mitral stenosis especially with associated large left and right atria, it is not unusual for the atrial septal orientations to vary. Hence, the transseptal puncture technique for

PTMC intervention should be tailored to individual patients.

In this communication based on extensive personal experience with transseptal catheterization, the author describes the transseptal puncture technique in PTMC using the Inoue balloon catheter technique. The author has performed PTMC in more than 500 consecutive patients. Transseptal catheterization was successful in all but one patient in whom the transseptal puncture resulted in cardiac tamponade and an aborted PTMC. PTMC was unsuccessful in only 4 patients: 3 during our very early experience with PTMC [8] and the one case complicated by cardiac tamponade. It is important to note that the transseptal puncture technique described herein may not be applicable to other mitral valvuloplasty techniques [25-29].

LANDMARK FOR OPTIMAL ATRIAL SEPTAL PUNCTURE

Frontal View

With right atrial angiography. Inoue modified the standard transseptal puncture method by recommending

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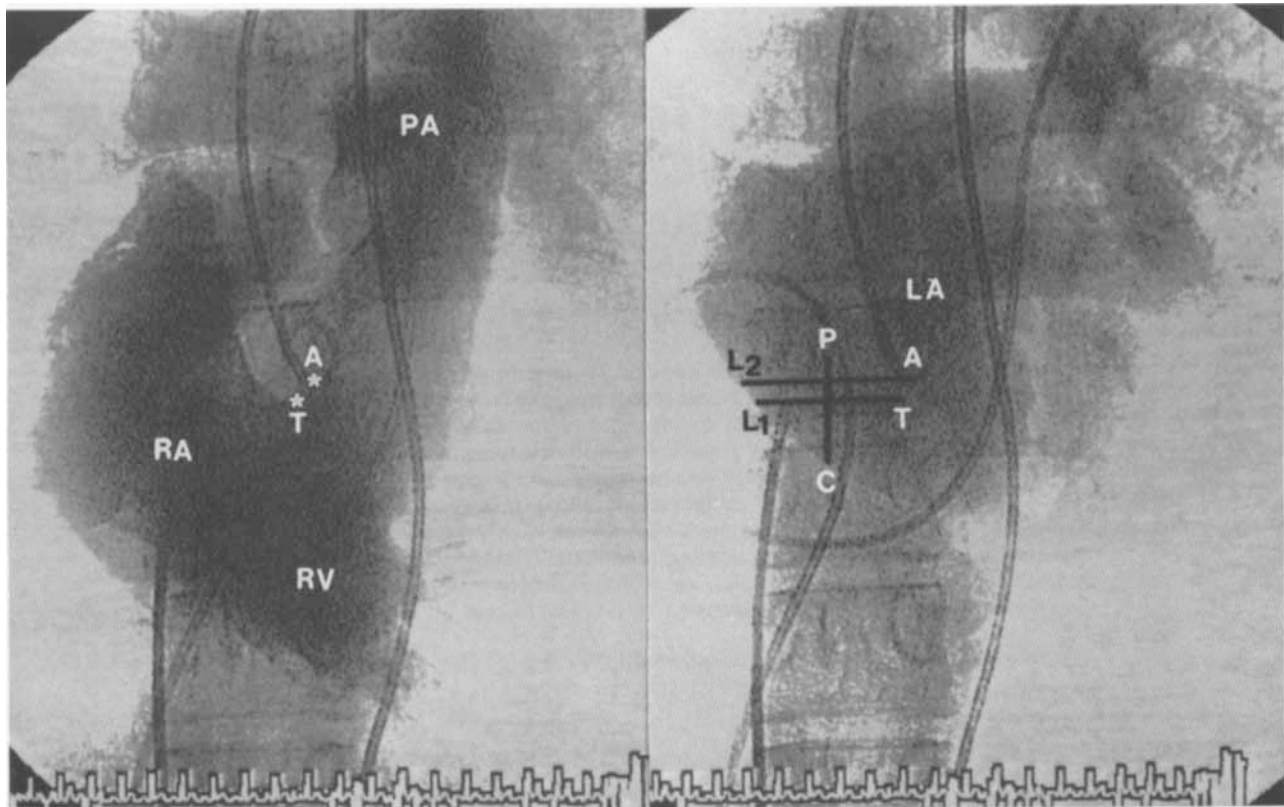


Fig. 1. Methods for choosing the primary puncture site. The upper end of the tricuspid valve at systole (T) is determined on a stop-frame frontal right atrial angiographic image (left panel) and translated to a stop-frame left atrial image (right panel). On the latter image, an imaginary horizontal line is drawn from Point T until it intersects the right lateral edge of the left atrium (L_1). A vertical line is drawn at the midpoint between T and L_1 (the "midline"), and its intersection with the caudal edge of the left atrium is regarded as Point C. The puncture site (P) is determined on the "midline" at about a vertebral body height above Point C. When the left atrial silhouette is clearly visible under fluoroscopy, right atrial angiography may be omitted; the

landmark for the upper end of the tricuspid valve (T) is substituted with the position of the aortic valve (A) marked by the tip of an arterial pigtail catheter touching the valve. An imaginary horizontal line is drawn from Point A to point L_2 , the site where the line intersects the right lateral edge of the left atrium (right panel). A vertical line (the "midline") is drawn at the midpoint between A and L_2 , and its intersection with the caudal edge of the left atrium is regarded as Point C. The puncture site is determined on the "midline" at a point about a vertebral body height above Point C. This primary target puncture site is memorized in relation to the vertebral bodies.

use of right atrial angiography to ensure a safe and optimized transseptal puncture for the PTMC procedure [10]. Right atrial angiography is performed during normal respiration until the aorta is visualized. The position of the upper end of the tricuspid valve at systole on a stop-frame frontal right atrial image is regarded as Point T (Fig. 1, left panel). The point is translated to the stop-frame left atrial image (Fig. 1, right panel). On the latter image, an imaginary horizontal line is drawn from Point T until it intersects the right lateral edge of the left atrium, denoted as Point L_1 . A vertical line is drawn at the midpoint between T and L_1 (the "midline"), and its intersection with the caudal edge of the left atrium is regarded as Point C. The puncture site is determined on this vertical line at a point (designated as point P) about one vertebral body height above Point C. This position is

then translated to an equivalent point to the fluoroscopic image of the vertebral bodies for performing the septal puncture.

This Inoue's modified angiographic method is especially suited for operators inexperienced with the technique. Furthermore, in extremely difficult cases of transseptal puncture, e.g., in the presence of a giant left atrium, it may be necessary to perform biplane (frontal and lateral) right atrial angiography to properly visualize the atrial septal orientation and relative anatomic relationships of the right atrium, the left atrium, the tricuspid valve, and the aorta, thereby facilitating safe and accurate puncture of the septum (Fig. 2).

Without right atrial angiography. Because in most cases of mitral stenosis, the left atrial silhouette is visible on chest X-ray film and under fluoroscopy, this author

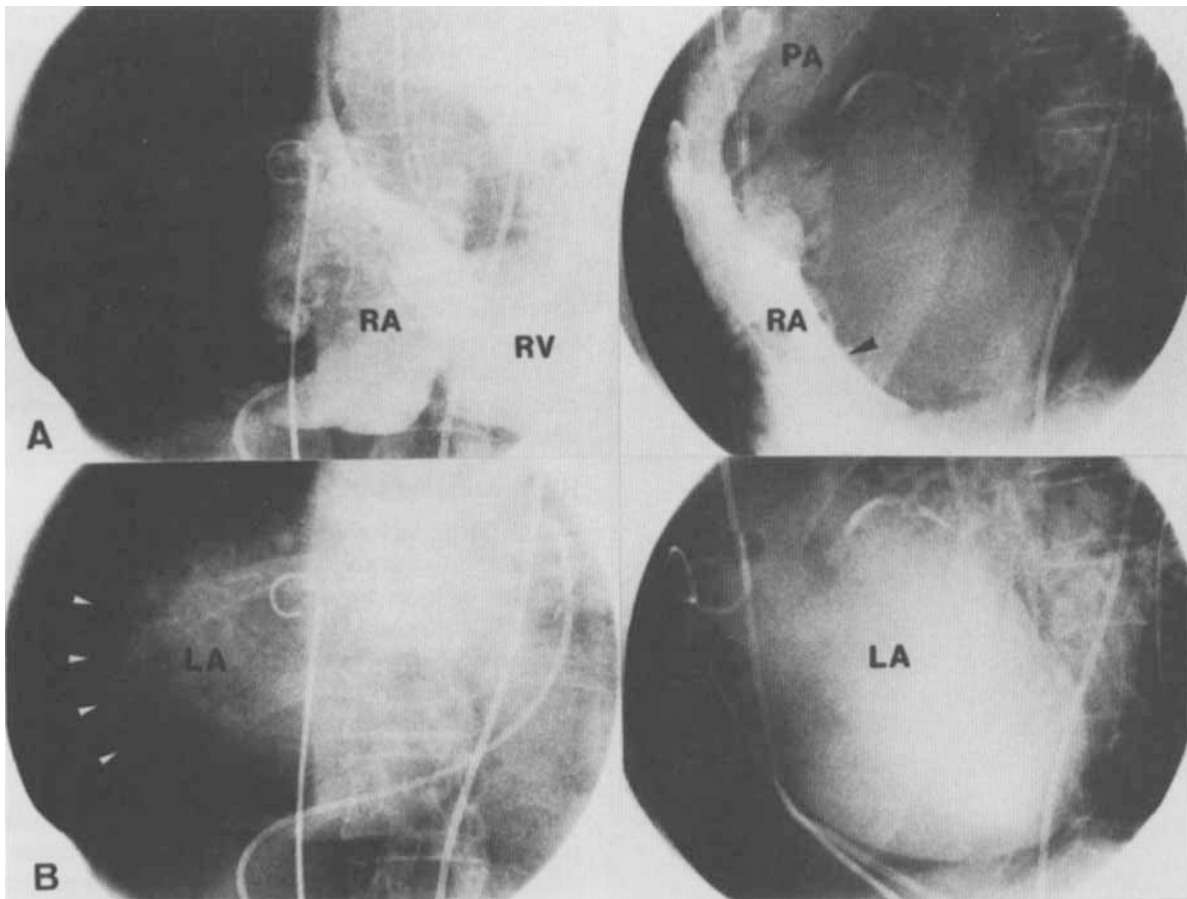


Fig. 2. Frontal (left panel) and lateral (right panel) biplane right angiograms performed to facilitate transseptal puncture in a patient with a giant left atrium. The markedly distorted atrial septal orientation is well demonstrated. The black arrow (right upper panel) indicates the transseptal puncture site, and white arrows (left lower panel) the lateral border of the left atrium. LA = left atrium; PA = pulmonary artery; RA = right atrium; RV = right ventricle.

has modified Inoue's method of targeting the transseptal puncture site without right atrial angiography. In this alternative method, the aortic valve is substituted as the landmark for the upper end of the tricuspid valve because the two valves are in close proximity to each other (Fig. 1). The position of the aortic valve (point A) is marked by the tip of an arterial pigtail catheter touching the valve. Under fluoroscopic frontal view an imaginary horizontal line is drawn from Point A to point L_2 , the site where the line intersects the right lateral edge of the left atrium. A vertical line (the "midline") is drawn at the mid point between A and L_2 , and its intersection with the caudal edge of the left atrium is regarded as Point C. The puncture site is determined on the "midline" at a point about a vertebral body height above Point C. This primary target site is memorized in relation to the image of the vertebral bodies. The "midline" derived from the author's alternative method is usually identical to that from Inoue's angiographic method.

Lateral View

In the lateral projection, locating an appropriate puncture site is less precise as the landmarks in this view depend very much on the left and right atrial sizes. However, the lateral view serves to confirm the appropriate posterior direction of the needle/catheter assembly and enables the atrial septal outline and orientation to be determined either by right atrial angiography (Fig. 2) or by the septal flush/stain method (Figs. 3, 4) described below.

Septal flush method. This method involves continuous flushing of the posteromedially directed needle with contrast medium as it is withdrawn caudally. This maneuver will outline the right atrial margin of the septum and its orientation (Figs. 3, 4) and a high septal puncture can thus be avoided. Puncture at a high site results in atrial septal dissection and at a low site in right atrial puncture.

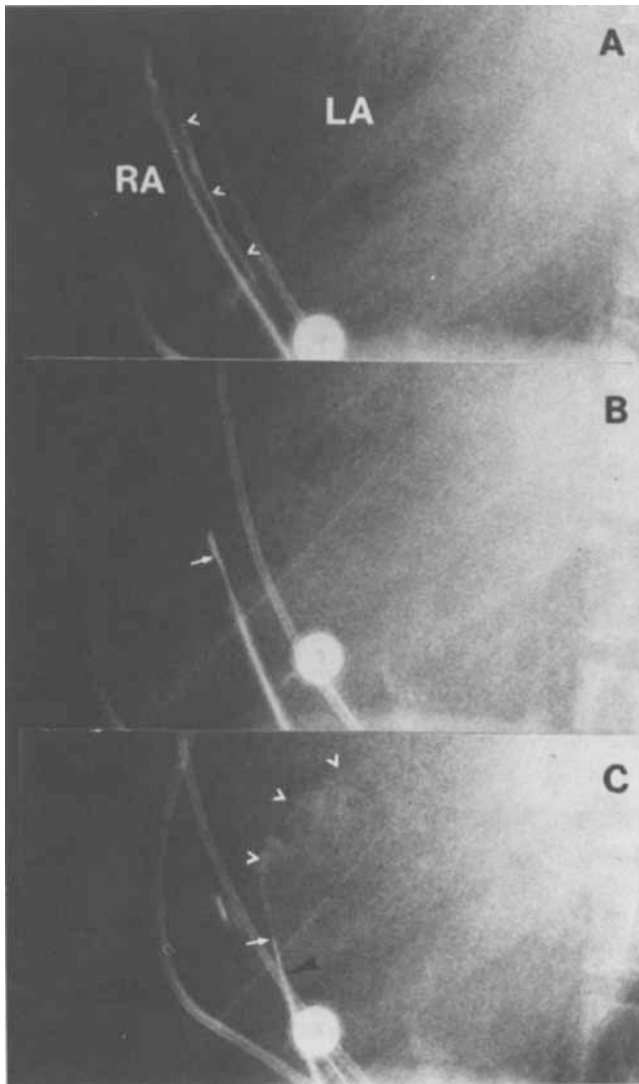


Fig. 3. Lateral fluoroscopic view showing the septal flush/stain method in a patient with a giant left atrium (LA). A. As the catheter/needle assembly is withdrawn caudally, it is flushed with contrast medium, which well delineates the right atrial margin of the septum (white arrowheads). The atrial septum projects markedly towards the right atrium (RA). B. A puncture is made at a high septal area where the septal plane is parallel to the direction of the catheter/needle. A vertical septal stain with contrast medium indicates a small septal dissection (white arrow). C. The catheter/needle is withdrawn and a puncture is made at a more caudal site (black arrowhead). Entry of the needle into the left atrium is confirmed by contrast opacification (white arrowheads).

Septal staining method. Staining of the atrial septum with contrast medium, originally described by Mullins as the “tag” [18] is used when there is no blood aspirated after an attempt is made at needle puncture. In this case the needle has either dissected the high septum or is caught in the thickened septum. When the high septum is

dissected, it appears stained in more vertical fashion (Figs. 3B, 4A). In this situation the catheter/needle should be withdrawn and septal puncture made at a lower site (Figs. 3C, 4B).

Usually the transseptal puncture site is in the inferior and posterior fossa ovalis. In cases wherein the puncture is made more caudally, it is made in the muscular septum (Fig. 4B). When the needle is caught in the thickened muscular septum, the stain takes on a more horizontal direction (Fig. 4C). When the catheter/needle is advanced, a “tenting” of the septum is observed before the septum is entirely pierced by the catheter/needle (Fig. 4D). Staining of the septum with a small amount of contrast medium is of no consequence since contrast medium is absorbed rapidly.

Right Anterior Oblique View

A 30° right anterior oblique (RAO) projection, which is identical to the projection used when manipulating the catheter balloon across the mitral valve [10], is very useful in both choosing an optimal atrial septal puncture site as well as avoiding puncture of other structures. Frontal and lateral biplane views are sufficient for experienced operators, but the RAO view is especially vital for inexperienced operators and in facilities where lateral X-ray projection is not available.

Stop-frame left ventriculogram. In choosing the puncture site in the RAO projection, a stop-frame of the diagnostic left ventriculograms in the RAO projection is used as a reference. In addition to assessing the degree of mitral regurgitation and left ventricular function, the ventriculogram outlines the anatomic relationship of the mitral orifice with the vertebrae, ribs, diaphragm, and diagnostic catheters and provides information on the mitral valve-left ventricular apex orientation (M-A axis) (Fig. 5, left panel).

Adjustment of primary target site. The primary puncture site as dictated by the landmarks in the frontal plane described above is usually adequate for the smooth advancement of the catheter balloon across the mitral valve. In our patient population the distance of this puncture point from the midpoint of the mitral annulus (point M) is usually about 1.2 times the vertebral width (or ~ 3.8 cm) when viewed in the RAO projection [unpublished observations] (Fig. 5, right panel). Nevertheless minor adjustments of the site may at times be necessary, especially in patients with relatively small left atria, very large left atria, or with more horizontally oriented M-A axes. The M-A axis usually aligns with the horizontal line in angles ranging from 30°–60°.

After the spring wire J-tipped stylet is inserted into the balloon catheter, the catheter assumes an inverted U shape in the left atrium. In order to facilitate the passage of the balloon across the mitral valve, the catheter loop

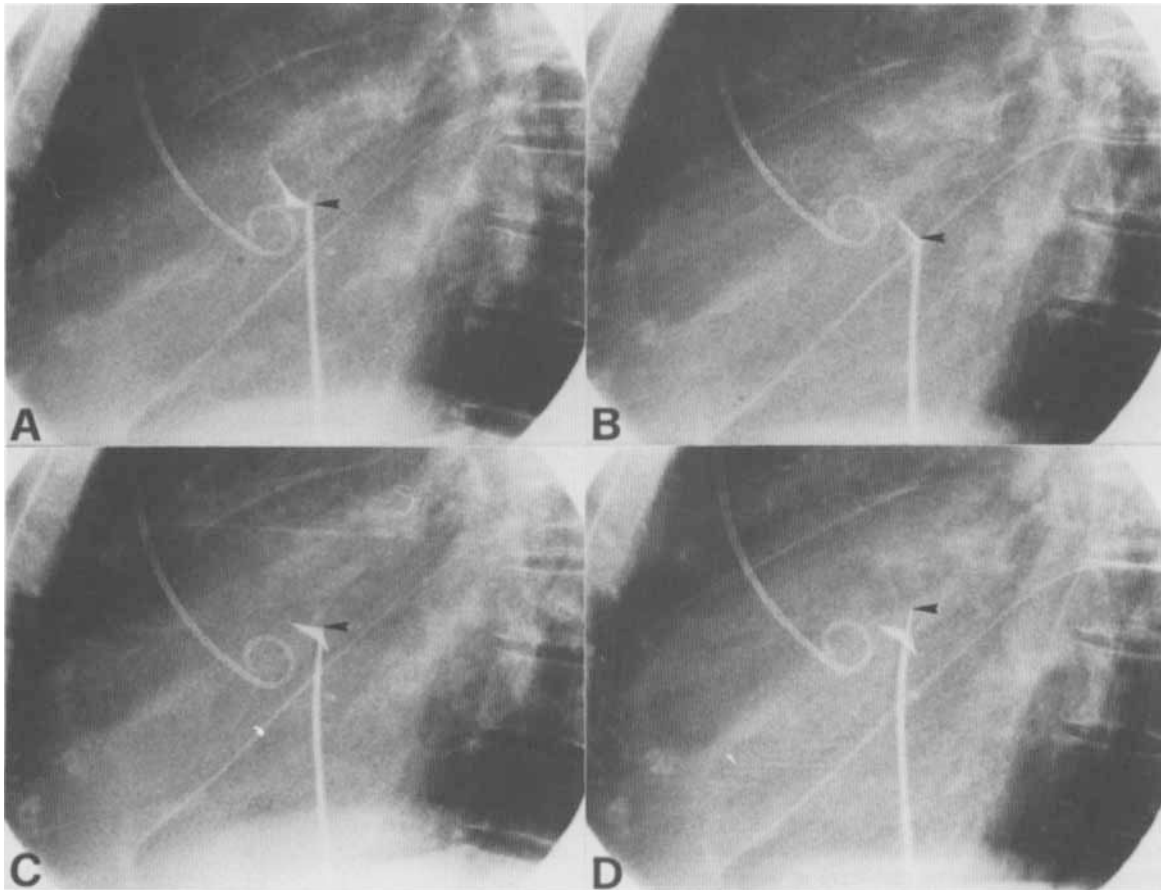


Fig. 4. Lateral fluoroscopic view showing the septal flush/stain method in a patient with a usual-size left atrium. A. As the catheter/needle assembly is withdrawn caudally, it is flushed with contrast medium, which outlines the right atrial margin of the septum. The tip of the catheter/needle (black arrow) is at the high anterior septum. B. The catheter/needle is withdrawn to set

its tip at the lower septum and the needle is advanced. C. Since the puncture is made in the thickened muscular septum, the needle is caught in the septum as demonstrated by the more horizontal septal stain. When the catheter/needle is advanced, a "tenting" of the septum is observed. D. The needle is carefully forced through the septum.

should be adjusted to align the direction of the balloon segment along the M-A axis, hence maintaining a co-axial relationship. Based on imaginary catheter loop, the puncture site is slightly adjusted in each individual patient, depending on the left atrial size and the M-A axis.

In patients with a relatively small left atrium, the primary target puncture site determined on the frontal view may be too close to the mitral orifice, thus creating two potential problems in crossing of the mitral orifice with the catheter balloon. First, if a puncture is made too close to the mitral valve (or relatively anterior in the septum), the catheter tip has a tendency to get caught in the posteriorly located pulmonary veins. Second, during manipulation of the catheter, the balloon segment takes a more vertical orientation relative to the M-A axis, thus disrupting the co-axial alignment. In such a situation, the stylet can be reshaped into a tighter loop or an alternative loop method [6,10] can be deployed to cross the mitral

valve. To circumvent these problems, however, one may use the RAO view to select a puncture site slightly more distant from the mitral valve by maintaining a more clockwise rotation on the catheter/needle. When viewed in the frontal plane before puncture, the site is slightly lateral to the "midline."

In patients with a large left atrium, the center of the atrial septum projects markedly toward the right atrium making transeptal access close to the center of the septum or the "midline" difficult. Furthermore, it is difficult to make a puncture at the primary target site chosen in the frontal plane because at this point the septal plane is more or less parallel to the direction of the catheter/needle and the puncture will result in septal dissection. Even when the puncture is successful at this point, subsequent insertion of a balloon catheter into the mitral orifice is difficult because the balloon catheter tip tends to be directed toward the posterior wall of the left atrium.

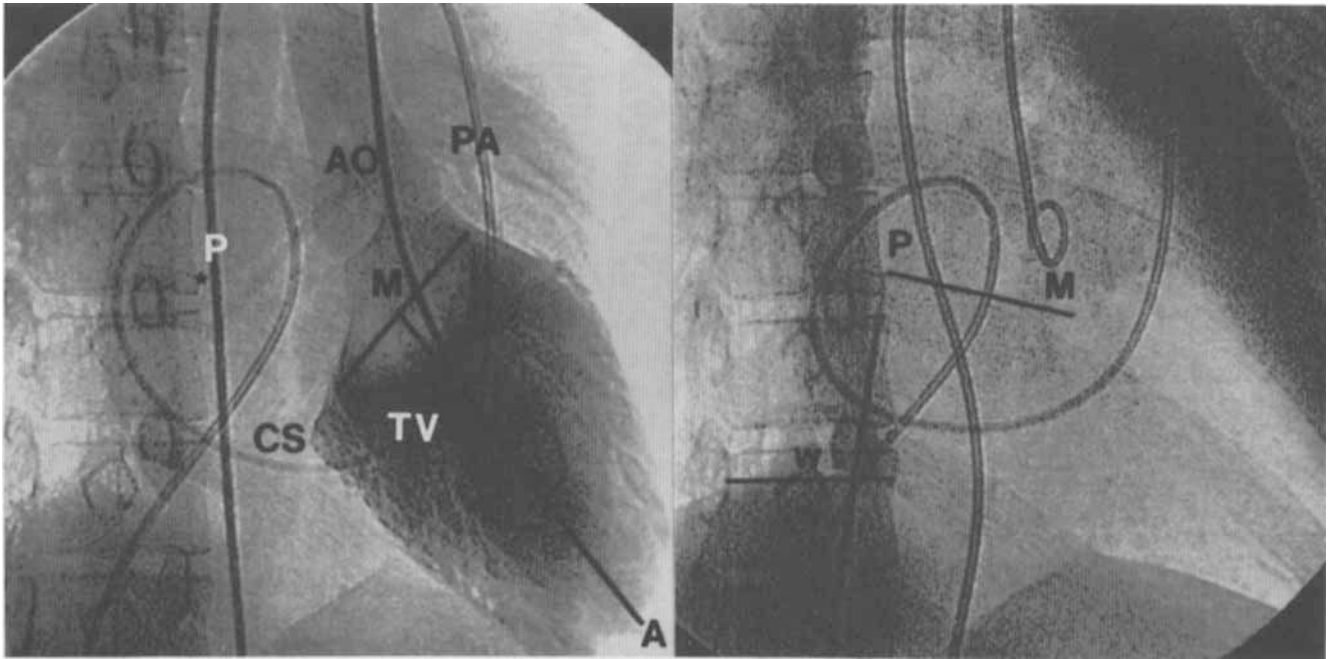


Fig. 5. Left panel, a stop-frame diastolic left ventriculogram in 30° right anterior oblique view. It is used as a reference in choosing the puncture site (P) in avoiding puncture of the aorta (AO), the tricuspid valve (TV), and the coronary sinus (CS) and in determining the mitral valve-left ventricular apex orientation (M-A axis), about 60° in this case. The ventriculogram also outlines the position of the mitral orifice in relation to the vertebrae, ribs diaphragm, and diagnostic catheters to be memorized for

manipulation of the balloon catheter across the mitral valve. Right panel, 30° right anterior oblique fluoroscopic view showing an appropriate distance and height of the puncture site (P) from the center of the mitral valve annulus (M). Usually the distance (PM) is about 1.2 times the vertebral width (w) and the puncture site (P) is slightly higher than the M point. See text for detailed discussions.

Therefore, in cases of large left atrium, the puncture site should be adjusted more caudally. The puncture site in this case is more distant from the mitral valve and usually on the same horizontal plane with the M point or even lower (more caudal). Because the balloon segment takes a more horizontal direction relative to the M-A axis, it may be necessary to reshape the J tip of the stylet into a wider curve to better facilitate the catheter balloon crossing the mitral valve.

In another potentially problematic scenario commonly encountered when the M-A axis is more horizontal (e.g., 30°), the puncture site should be placed more caudally. It must be stressed that when the puncture site is adjusted more caudally for any reason (large left atrium or more horizontally oriented M-A axis), a definite septal outline be visualized either by the septal flush method or by the right atrial angiography in the lateral view before proceeding with septal puncture. Otherwise, one runs the risk of cardiac perforation resulting from right atrial puncture.

Avoiding inadvertent puncture of the aorta, tricuspid valve, and coronary sinus. In the RAO projection, the intended puncture site is clearly separated from the aorta, the tricuspid valve and the coronary sinus (Fig. 5).

Therefore, when the transeptal needle is pushed forward only either the septum or the right atrial wall is punctured. The latter situation can be avoided by making sure the needle tip is remote from the right lateral border of the left atrium and above the center of the mitral annulus (M point) in the frontal projection before making a puncture. When a puncture is to be made at a site lower than the M point and closer to the lower edge of the left atrial silhouette in the frontal view, a definite septal outline in the lateral view should be visualized either by the septal flush method or by right atrial angiography as stated above.

INAPPROPRIATE PUNCTURE SITES

The following sites should not be punctured, lest cardiac tamponade ensues or lest there arises difficulty in manipulating the catheter balloon across the mitral orifice.

High Atrial Septum

If the puncture is made too high (cephalid) at the thick muscular wall of the upper edge of the fossa ovalis, a strong resistance is met during needle puncture and no

blood is retrieved upon aspiration. Upon injecting a small amount of contrast medium, the septum shows a more vertical stain indicating a small septal dissection (Fig. 3B). When this occurs the catheter/needle should be withdrawn and septal puncture attempted at a lower (caudal) site (Fig. 3C). Otherwise, if the catheter/needle is forged forward, extensive septal dissection may result because the catheter/needle is more or less aligned parallel with the septal plane. The dissection may lead to cardiac tamponade. Even if the transseptal puncture is successful, subsequent manipulation of the catheter will be limited by the thickened septum.

Anterior Atrial Septum

If the puncture is made left (medial) to "the midline," it will be in the anterior atrial septum. This site is too close to the mitral orifice and the catheter tends to point more posteriorly. This will make it difficult to manipulate the catheter balloon across the mitral orifice unless the alternative loop method [6,10] is used. Furthermore, when the puncture is also made lower in the region medial to "the midline," there is a risk of injury to the tricuspid valve or the coronary sinus. Therefore, septal puncture should not be made at a site medial to "the midline."

Coronary Sinus

The ostium of the coronary sinus is just above the tricuspid valve. Viewed in the RAO projection, it is located near the Swan Ganz catheter placed in the pulmonary artery (Fig. 5, left panel). When the catheter enters this site, the operator may erroneously assume that its tip has entered the fossa ovalis. Puncturing the coronary sinus will lead to intractable hemorrhage, which requires surgical intervention.

Vicinity of Right Lateral and Inferior Left Atrial Edge

There is no atrial septum in the region beyond or near the right lateral and inferior borders of the left atrial shadow viewed in the frontal projection. This is especially true in patients with a large left atrium. If this region is punctured, the catheter/needle may perforate through the right atrial wall and then enter the left atrium (the so-called stitching phenomenon). After the guide wire is placed in the left atrium and the catheter is withdrawn, cardiac tamponade ensues. This was precisely what happened in the only instance of cardiac tamponade encountered by the author in a patient with a giant left atrium.

Aorta

Inadvertent puncture of the aorta, as confirmed by contrast injection or pressure recording, is usually un-

eventful if the needle is withdrawn immediately [18]. However, should the operator unknowingly advance the catheter into the aorta, it should not be withdrawn. The patient should be sent for emergency surgery with the catheter left in the aorta.

PROCEDURE OF ATRIAL SEPTAL PUNCTURE

Catheter/Needle Fitting Exercise

The atrial septal puncture is performed using a 7F or 8F Mullins transseptal catheter (with or without its sheath) and a Brockenbrough needle. The sheath is recommended for inexperienced operators to prevent inadvertent perforation of the catheter by the needle during its insertion. A catheter/needle fitting should be performed before its insertion into the patient. First, fully insert the transseptal needle until it extends beyond the catheter. Then withdraw the needle until its tip is concealed slightly (2–3 mm) within the tip of the catheter. The operator should place his or her right index finger as a stopper on the needle between the direction indicator and the catheter hub to prevent the needle from moving forward and protruding from the catheter tip (Fig. 6).

Placement of Transseptal Catheter and Needle

Under local anesthesia, a J-tipped 0.032-inch guide wire is inserted via the right femoral vein into the superior vena cava. The transseptal catheter is inserted over the guide wire into the vena cava and the guide wire is removed. The catheter is aspirated and flushed. Then, the Brockenbrough transseptal needle is inserted into the catheter and carefully advanced under fluoroscopic view until its tip is about 2–3 mm proximal to the catheter tip. The needle is allowed to rotate freely during its passage. A 5 cc plastic syringe containing contrast medium is attached to the needle. With the right hand, the needle is aspirated and flushed with contrast medium while the left hand keeps the needle from moving forward. The right-hand stopper-finger, with its predetermined position and angulation, is now firmly kept between the catheter hub and the direction indicator of the needle to prevent the needle from moving forward. Extreme care should be taken not to let the needle slip further during subsequent manipulation of the catheter/needle.

Catheter/Needle Manipulation

Under frontal fluoroscopic view, the needle-fitted transseptal catheter with its direction indicator pointing about 4 o'clock is slowly withdrawn downward (caudally) from the superior vena cava. In the process a sudden sharp movement towards the left may be observed when the tip of the transseptal assembly falls over the limbic ledge and enters the fossa ovalis [15,21]. However, in cases of mitral stenosis, the motion is often

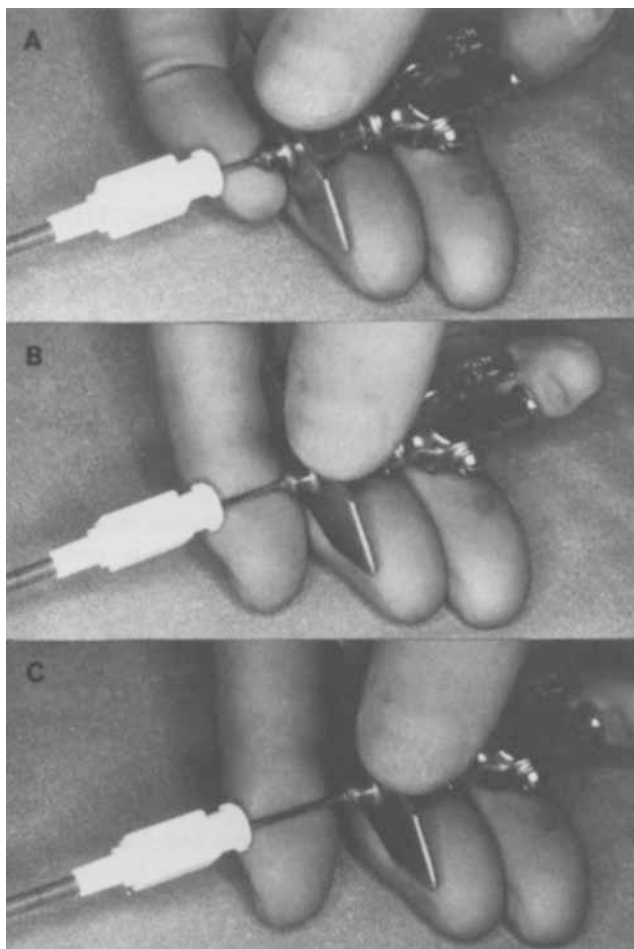


Fig. 6. Catheter/needle fitting exercise. After the needle is withdrawn, until its tip is concealed slightly (2–3 mm) from the catheter tip, the index finger is used as a stopper on the needle between the direction indicator and the catheter hub. This is to prevent the needle from moving forward and protruding from the catheter tip. The depth (A and B) and the angle of the stopper-finger (C) is adjusted according to the distance between the direction indicator and the catheter hub in each catheter/needle set.

difficult to detect because the atrial septal bulging towards the right atrium makes the fossa ovalis more shallow. In either case, a clockwise rotation is applied to the direction indicator to place the catheter/needle perpendicular to the atrial septum. As it is withdrawn caudally to the primary target site, the catheter tip is aligned with the “midline.”

At this point the catheter/needle direction varies according to left atrial sizes. In general, it is at 4 o'clock in relatively small left atrium (< 4 cm), between 4 and 5 o'clock in a usual-size left atrium, and at 6 o'clock in a large left atrium (> 5 cm). However, it should be noted that the groupings for small, usual and large left atrium

by M-mode echocardiograms are arbitrary, and the needle direction may vary considerably among patients with a similar size left atrium. Usually it is not difficult to engage the catheter tip at the primary target site in patients with relatively small or usual-size left atrium. In our patient population, 10% had a relatively small left atrium, 50% a usual-size left atrium (4–5 cm) and the remaining 40% a large left atrium (> 5 cm), including 5% with a giant left atrium (≥ 7 cm). The left atrial size ranged from 3.0–9.2 cm (unpublished observations).

If the atrial septum bulges markedly toward the right atrium, especially in cases of a giant left atrium, it is difficult to align the catheter tip with the “midline” and perpendicular to the septum. The catheter tip faces a strong resistance at 4 o'clock when it touches the bulged septal surface. As the needle is being rotated clockwise, the catheter/needle will give way suddenly. In effect, the needle tip flips over the crest of the bulge and towards the right side of the patient pointing to 9 o'clock. To prevent this, the catheter should be pressed slightly against the septum as the needle is being rotated clockwise to 6 to 7 o'clock. At the same time, a slight counterclockwise twist is applied to the catheter with the left hand to counter any excessive clockwise rotation of the needle. If the crest of the bulge happens to be at the “midline,” it is not possible to make a puncture on the line. In this case the puncture site is settled in the region slightly lateral to “the midline.”

When the septal bulge begins in the upper septum, the catheter/needle being withdrawn from the superior vena cava takes a lateral course to the “midline.” In this case, turning the needle to the 3 o'clock direction may lead the catheter/needle to a medial position. If not, the needle alone can be withdrawn slightly, and the floppy tip of the catheter should tend to flip medially. Then the needle is advanced slowly and carefully to bring its tip back to the original position while keeping the catheter tip in the medial position. If the above means also fail to place the catheter/needle medially, the latter is withdrawn further downward and close to the lower edge of the left atrium (passing the caudal end of the bulge). With the needle pointing toward the left (about 3 o'clock), the catheter tip is allowed to shift medial to the “midline” and then carefully advanced cephalad. A clockwise twist is made to the needle and the catheter tip is steered to or near the target point.

If the initial pass of the transeptal catheter/needle is not successful in engaging it at an appropriate puncture site, the needle is removed from the catheter and the second attempt is begun by repositioning the catheter in the superior vena cava over a guide wire. The alternative is to reposition the catheter/needle high in the right atrium. This is done by setting the needle in the 12 o'clock direction (ventrally) and carefully moving the

catheter/needle upward (cephalad) while slightly rotating the direction indicator of the needle clockwise and counterclockwise to make certain the catheter tip is free and not caught against the right atrial appendage or its free wall.

Septal Puncture

When the operator is satisfied with the intended puncture site, the catheter/needle is pressed firmly against the septum. Usually cardiac pulsations (so-called septal bounce) are felt by the right hand holding the catheter/needle. While keeping the catheter firmly against the septum to prevent it from slipping away from the puncture site, the operator releases the stopper-finger and forcefully advances the needle forward. The needle is aspirated and contrast medium is injected to confirm its entry into the left atrium. If no blood is aspirated, the needle either has dissected the high septum or is caught in the thickened septum. Staining of the septum with injection of a small amount of contrast medium easily distinguishes the two (Figs. 3, 4). When the high septum is dissected, it is stained in more vertical fashion (Fig. 3B). In this situation the needle is withdrawn and septal puncture is made at a lower (caudal) site. When the needle is caught in the thick septum, the stain takes more horizontal orientation (Fig. 4C). In this case the catheter/needle is carefully forced across the septum as described below or the puncture is attempted at another site. It is not possible to differentiate dissection of the high septum from entrapment of the needle in the thick septum with pressure monitoring. This is another reason why the author performs the transseptal puncture without constant pressure monitoring.

Confirmation of Left Atrial Entry

After entry of the needle in the left atrium is confirmed, first by contrast medium injection followed by pressure recording and blood oximetry, the needle direction is set toward 3 o'clock (left side of the patient). If there is no or little resistance, the catheter/needle is advanced forward about 2 cm into the left atrium. Then, the catheter alone is advanced another 2 cm (or until the tip of the transseptal sheath meets a resistance at the septum if sheath is used), while the needle is being withdrawn.

When a marked resistance is encountered, a sustained force is applied to the catheter/needle. After several cardiac beats, not infrequently a "give" is felt or seen on fluoroscopy when the catheter/needle finds its way into the left atrium. If this means fails to place the catheter/needle across the septum, a Bing stylet, which has a blunt tip, is inserted and extended beyond the needle. The catheter/needle is carefully forced through the tough septum by forward push with the right hand while applying counter resistance with the left hand. During the

process the operator must be prepared to withdraw the needle as soon as the catheter enters the left atrium, lest the excessive forward momentum carries the needle forward and perforate the left atrial wall causing cardiac tamponade. Upon removing the needle after the catheter is placed in the left atrium, heparin, 100 units/kg body weight, should be given immediately through the catheter. After baseline hemodynamic studies, including simultaneous measurement of cardiac output, PTMC is performed.

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