Considerations Regarding the Technique for Transseptal Left Heart Catheterization

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The transseptal method of left heart catheterization\textsuperscript{1-4} has been widely employed in recent years, and in many laboratories no important complications associated with its use have been reported.\textsuperscript{5-15} Increasing application of the technique as originally employed in this laboratory\textsuperscript{5} and the modification in which an angiographic catheter traverses the interatrial septum\textsuperscript{16-20} has been accompanied by several reports of problems and complications. In general, these difficulties have been related either to the design of the equipment, to faulty manipulation of the transseptal needle and catheter resulting in perforation of the cardiac wall with cardiac tamponade, or to use of the procedure in patients now considered to be unsuitable for study by this method. Two and one-half years ago, problems of this nature in our own laboratory prompted several important improvements in the technique, which appear to have obviated such complications. It is the purpose of the present report to describe these modifications in instrumentation and methods, to review the major problems that have been reported, and to discuss the role of the technical changes described in avoiding complications during transseptal left heart catheterization.

Modifications in the Equipment for Transseptal Left Heart Catheterization

The Needle

The transseptal needle, described in detail previously,\textsuperscript{10} has proved generally satisfactory, although breakage of the no. 21-gauge needle tip at its junction with the no. 18-gauge stock has been reported by other investigators\textsuperscript{21-23}; occasionally, improper alignment of the indicator handle and the needle curvature has been observed.\textsuperscript{28} On several occasions in this laboratory and elsewhere,\textsuperscript{24, 25} the needle has perforated the wall of the catheter while being advanced toward the right atrium. In view of this problem, the needles employed are now equipped with a blunt stylet.* Somewhat similar devices have been described,\textsuperscript{19, 20, 25} while Bevegård and associates\textsuperscript{18} have employed instead a metal sheath over the needle. The stylet, shown in figure 1 (A), protrudes approximately 2 mm beyond the needle point and is left in place until the needle point has been advanced beyond the most distal side holes of the catheter, as described below.

The precise curvature of the needle is not critical and can be modified manually before insertion into the catheter. Although the curvature supplied by the manufacturer is satisfactory when the left atrium is of normal size, the curve of the needle should be straightened somewhat when a greatly enlarged left atrium bulges into the right atrium, and slightly more curvature may be occasionally required to engage the interatrial septum when the right atrium is enlarged.

The Catheter

Perforation of the heart, sometimes resulting in cardiac tamponade, has been reported during transseptal catheterizations.\textsuperscript{22, 26-34} These perforations have generally involved penetration of the left or right atrial wall. In 1,300 transseptal catheterizations performed in this laboratory, four fatal incidents occurred more than 2½ years ago, before the adoption of the changes in technique described in this report, and all resulted from

*Constructed by K. Bolen of the Instrument Fabrication Section, National Institutes of Health, Bethesda, Maryland.
left atrial perforation. In other large experiences there have been fewer fatalities, and in our last 350 consecutive transseptal catheterizations, there has been only one major complication; this incident was related to puncture of the aorta in a patient with marked kyphoscoliosis (see below). In the patients in whom left atrial perforation occurred, a relatively stiff Teflon transseptal catheter was used, and a new catheter was therefore designed with the primary objective that it be soft. In addition, a more gradual taper was provided at the tip, the end and side holes were designed to minimize clot formation, and the side holes were arranged to avoid their penetration by the needle. The catheter (fig. 1B) is composed of white, radiopaque polyethylene.* Since variability occurs in the length of the needles supplied commercially, and changes in catheter length can occur with sterilization, each catheter is constructed to match a particular needle, being 1.0 cm shorter than the needle. The six side holes, arranged in parallel on opposite sides of the catheter, are considerably smaller than the end hole so that adequate irrigation of the tip as well as the side holes can be provided. It is likely that one episode of transient hemiparesis observed in this laboratory

several years ago following catheter irrigation was the result of dislodging a clot from the tip of a catheter in which the side holes were large in relation to the end hole.

In wrapping the catheter prior to sterilization, a curved stylet is introduced and care is taken to place the side holes laterally in relation to the curvature of the catheter (fig. 1B). If the side holes are placed on the greater curvature of the catheter, accidental passage of the needle tip out one of the holes can readily occur and result in buckling of the catheter tip against the septum at the time of puncture. It is then both difficult and hazardous to advance the catheter across the interatrial septum, several complications apparently having resulted from passage of the needle point out one of the spirally arranged holes present in transseptal catheters employed previously.36, 37

**The Catheter-Tip Occluder**

Devices for occluding the end of a tapered-tip catheter, similar to the one shown in figure 2 (B and C), have been described previously,25, 36, 38 its use with the transseptal catheter for occluding the catheter tip during angiography was originally suggested to us by Dr. J. M. Criley. The catheter-tip occluder+ is frequently employed during transseptal left heart catheterization in this laboratory, and it has proved to be of great assistance in two areas. First, during selective left atrial or left ventricular angiography, it occludes the end hole of the catheter (fig. 2C), thereby preventing catheter recoil and intramyocardial injection of contrast material; for this purpose the tip occluder is used in conjunction with a proximal Y-adapter (fig. 2A). Secondly, when bent into a suitable shape (fig. 2B), the device has been found extremely useful for directing the transseptal catheter from the left atrium across the mitral valve into the left ventricle (see technique, outlined below).

**Modifications in the Technique of Transseptal Left Heart Catheterization**

**Preliminary Steps**

Prior to inserting the transseptal catheter, the needle with its stylet in place is inserted into the catheter. With the tip of the stylet just inside the end hole of the catheter, the distance between the proximal end of the catheter and the hub of the needle is recorded by marking or cutting a piece of paper (fig. 1C, position 1). The needle and stylet are then advanced 2 or 3 mm until the needle tip lies just within the catheter tip, and the second distance is noted (fig. 1C, position 2). Subsequently, after the catheter has been inserted and its tip positioned in the right atrium, the needle and stylet are advanced until the hub end of the needle reaches position 1; the stylet is then removed, the needle is irrigated and advanced to position 2. This procedure assures that the point

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*Becton, Dickinson and Company, Rutherford, New Jersey; tip occluder no. 5535.
†U. S. Catheter and Instrument Corp., Glens Falls, New York.
of the needle lies beyond the side holes and just within the catheter tip before manipulations within the right atrium are initiated.

Blunt Dissection

An extremely common cause of problems in performing transseptal puncture by the percutaneous technique, and subsequently in manipulating the transseptal catheter within the chambers of the left heart is, in the author’s opinion, lack of tactile appreciation of the movement of the catheter tip. As a result, the structures engaged by the catheter tip are not recognized, and the degree of pressure exerted against them is uncontrolled. These difficulties are often caused by binding of the catheter in the groin, at the site of the percutaneous puncture. Prior to inserting the catheter, therefore, the performance of adequate blunt dissection down to the femoral vein, by spreading with a blunt clamp or through a small skin incision, is of great importance. Moreover, once the catheter is inserted, the tissues should again be dissected away by spreading a clamp placed alongside the catheter, until the catheter can be moved freely back and forth.

Puncture of the Interatrial Septum

The number of landmarks used to ascertain the proper location for puncture of the septum has increased since the original description. In patients with left atria of relatively normal size, the position of the atrium should first be identified on overpenetrated, anteroposterior radiographic views of the heart obtained with barium swallow. With these films as a guide, the relative positions of the left atrium, the spine, and the left main-stem bronchus can then be identified readily under the fluoroscope. The usual site for septal puncture in patients having normal or slightly enlarged left atria lies just above the lower shadow of the left atrium, approximately at the junction of the lateral and middle thirds of the spine, and suitably below the left main-stem bronchus (fig. 3-1). If a sufficiently medial location cannot be reached, the patient’s hips and legs are moved to the right 1 or 2 inches, the shoulders remaining in position. Thus, as others have noted the proper site for puncture in patients without left atrial enlargement is higher than that previously advocated in patients with left atrial enlargement and is often situated at the middle of the cardiac silhouette, or somewhat higher.

Additional landmarks can be identified by manipulations within the right atrium. It is frequently our custom first to position the needle and catheter high in the right atrium; the needle hub and catheter tip are then rotated gently to a 45° posteromedial direction, and the catheter tip and contained needle are withdrawn downward slowly. A distinct movement of the catheter tip laterally, to the patient’s right, and then medially is noted as the bulge of the aorta and the “limbic ledge” are traversed. The proper site for puncture is then found below and posterior to this bulge, as the catheter tip is gently advanced posteromedially, reaching the fossa ovalis just below the limbic ledge. This technique avoids engagement of the catheter tip in the ostium of the coronary sinus. As has been pointed out by Aldridge, when the catheter tip is maintained in this position with steady, moderate pressure, it is often possible to perforate the interatrial septum without protrusion of the needle. In many instances, however, we have preferred making the puncture to be assured that the no. 21-gauge needle lies free within the left atrium, before the catheter is advanced across the interatrial septum.

In patients with greatly enlarged left atria, the site, previously described at the junction of the middle and lower thirds of the right atrial silhouette, is usually satisfactory. In many of these patients, the bulge of the left atrium into the right atrium can be appreciated easily by rotating the needle hub posteriorly in an 180° arc. The catheter is then deliberately positioned on the center of this bulge for performing the puncture (fig. 3-1a). Frequently, the optimum direction for septal puncture under these circumstances is in a more posterior direction than that em-
Figure 3

(1) Position of transseptal catheter and contained needle against the interatrial septum prior to transseptal puncture in patients with normal or slightly enlarged left atria, and with greatly enlarged left atria (1a). (2) Position of catheter in left atrium after transseptal needle is withdrawn. (3) Position of catheter and catheter tip occluder as tip of catheter is directed across mitral valve.

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ployed in patients without left atrial enlargement, that is, 60 to 90° from the horizontal plane, rather than 45°. It should be emphasized that the bulge of the aorta, described in patients with left atria of normal size, sometimes cannot be appreciated when the left or the right atrium is greatly enlarged. Under these circumstances, the lower border of the left atrial shadow and the left main-stem bronchus provide the best landmarks, the latter being identified by comparison of the fluoroscopic image with previously obtained overpenetrated roentgenograms of the heart. If a retrograde arterial catheter has been inserted and its tip positioned in the aortic root, injection of a small amount of contrast substance is useful in ascertaining the position of the aorta.19, 31

During puncture of the interatrial septum, the position of the catheter and needle is observed continuously on the fluoroscope. The puncture is accompanied by a rapid medial movement of the catheter and needle, which is easily observed by the operator and is usually associated with a palpable, sudden decrease in resistance. The intracardiac pressure at the tip of the needle is monitored continuously on the oscilloscope during the puncture; a short length of flexible tubing between the hub of the needle and the tubing to the pressure transducer facilitates this procedure. It is most important to stabilize the catheter...
firmly with one hand during the puncture to prevent it and the needle from sliding forward and upward within the right atrium, should the needle point fail to engage the tissue of the septum. Puncture of the right atrial wall and appendage has been reported on two occasions during attempted transseptal puncture in patients with enlarged right atra, suggesting that the catheter and protruded needle had moved upward a considerable distance.

When a satisfactory left atrial pressure pulse can be recorded through the needle, it should be possible to aspirate left atrial blood freely through its lumen. If blood cannot be aspirated, the needle and catheter are not advanced further. Usually the needle is then retracted and the puncture is repeated. On several occasions, inability to record undamped pressure or to aspirate blood has been shown at subsequent operation to have been caused by organized thrombus in the left atrium involving the region of the interatrial septum. Since it is not possible to irrigate the catheter adequately when the needle is in place and if several attempts at septal puncture are necessary, the needle should be removed, and the catheter should be aspirated and flushed before additional attempts at puncture are made.

Once needle puncture of the interatrial septum has been achieved, it is important when the left atrium is small to rotate the needle hub about 15° anteriorly (to a position 30° from the horizontal plane) before the needle and catheter are advanced together into the left atrium; this maneuver avoids contact of the posterior wall of the left atrium by the needle. After this maneuver and the precautions listed above, gentle and sustained forward pressure is applied to the catheter and needle, while left atrial pressure is monitored continuously at high sensitivity. If the tracing becomes damped, pressure is released and the needle is rotated slightly more medially.

As with the needle puncture, as the catheter traverses the septum, the sudden medial and upward movement is usually appreciated readily both manually and visually. Once the catheter and needle have crossed the septum, the needle is withdrawn slightly as the catheter is advanced over the needle to lie within the left atrial shadow (fig. 3-2). The catheter may enter a left pulmonary vein, but entry into the left atrial appendage should be avoided if possible. The needle is withdrawn completely once the catheter is positioned as shown in figure 3 (2).

**Catheterization of the Left Ventricle**

Use of the catheter-tip occluder as a guiding stylet has greatly facilitated entry into the left ventricle, and the needle is no longer used for manipulation of the catheter. Before insertion of the occluder, it is bent as shown in figure 2 (B). Then, with the transseptal catheter positioned as in figure 3 (2), the occluder is inserted into the catheter while the curvature of the occluder wire is maintained in a medial direction. As the tip of the occluder crosses the septum and approaches the end of the catheter, the tip of the catheter will swing downward and anteriorly toward the mitral valve. If this does not occur, the catheter tip is probably situated in a pulmonary vein; this may be verified, if necessary, by injecting a small amount of contrast material, and the tip freed by pulling the catheter back slightly. The occluder tip is positioned 2 or 3 cm back from the tip of the catheter, and it is then usually rather simple to advance the catheter over the stylet into the left ventricle, by using slight counterclockwise rotation to reach the anteriorly placed mitral valve (fig. 3-3). The tip of the occluder is not advanced to the end of the catheter during these manipulations, since this would render the distal portion of the catheter rigid and potentially hazardous. The Y-adapter (fig. 2A) is not usually employed during these manipulations, but is added for selective angiography; a less acute bend in the occluder wire is usually desirable for left ventriculography.

**Comment**

The modifications in the equipment and technique for performing transseptal left heart catheterization described in the present report
appear to have overcome the major difficulties encountered in recent years with this procedure. It seems likely that several factors contributed to the problems that were reported following the initially uncomplicated use of this method in large groups of patients. First, it seems probable from our own experience, and that of others,\(^a\) that a number of complications were a result of the apparent technical simplicity of the procedure; it has since become clear that the transseptal technique is not always simple, particularly when the precautions described above are taken, and, as with any other approach to the left heart, it should be performed only by thoroughly trained personnel. Secondly, the modification in which a large catheter is passed across the interatrial septum into the left heart chambers obviously entailed the use of increased manual pressure; thus, more technical facility, as well as intimate knowledge of the anatomy of the left heart chambers, was required. Finally, although the major difficulties with the modified transseptal technique now appear to be solved, its initial immediate acceptance by many laboratories for studying patients with all varieties of cardiac lesions inevitably resulted in problems, until patients not suitable for study by this method were recognized.

It now seems clear that the transseptal method should not be employed, or should be used with particular caution in several situations. Experience in this laboratory has delineated the following situations of this nature: (1) patients found to have giant right atria, in whom the interatrial septum cannot be engaged readily by the tip of a transseptal catheter; (2) patients having important rotational anomalies of the heart or great vessels, and patients with marked scoliosis of the thoracolumbar spine; (3) patients with marked dilatation of the aortic root, such as those with aortic aneurysm or free aortic regurgitation, particularly when this finding is associated with a small left atrium. Puncture of the aorta with the no. 21-gauge needle generally is uncommon and may carry little hazard if recognized by monitoring pressure at the needle tip before the catheter is advanced.\(^7\), \(^8\), \(^10,\) \(^23,\) \(^40,\) \(^41\) however, complications have occurred with aortic puncture,\(^31,\) \(^32\) and nonfatal bleeding into the mediastinum, which occurred in a patient with marked scoliosis in whom aortic pressure was obtained during an attempted transseptal study, constitutes the only major complication of transseptal puncture in 350 recent studies, as mentioned previously; (4) patients on anticoagulant therapy; in this laboratory, such patients are returned to near-control levels of prothrombin time before transseptal puncture is performed; (5) patients with a history of recent systemic arterial embolization. In this situation, we perform only needle puncture of the interatrial septum, and enter the left ventricle simultaneously by the retrograde arterial route. This practice is supported by experience from other laboratories, describing probable dislodgement of an adherent thrombus from the left atrial wall during manipulation of a transseptal catheter within this chamber.\(^23,\) \(^42\) The development of a thrombus at the site of transseptal puncture appears to be rare, a single instance having been noted post mortem in a patient who died following operation.\(^43\) Another exceedingly rare occurrence consequent to transseptal catheterization is persistence of a defect at the site of puncture. This finding has been observed in this laboratory in a single patient.\(^44\)

In many laboratories, the transseptal approach is the method of choice for performing left heart studies. In our own laboratory, it is always employed for entry into the left heart chambers when catheterization of the left atrium is indicated, as in patients with mitral valve disease. It is also used to gain access to the left ventricle when none of the above relative contraindications exists, although in many patients with isolated aortic valve disease, or with lesions of the left ventricular outflow tract, hemodynamic and angiographic studies can be obtained more satisfactorily by the retrograde arterial method. Moreover, in older patients with isolated calcific aortic stenosis, anterior percutaneous
puncture of the left ventricle has proved efficacious. Thus, although the transseptal route is frequently employed in this laboratory, there are relative indications and contraindications to its use, and it is anticipated that consideration of these factors, together with the improvements in equipment and technique that have been described, will greatly enhance the safety of this procedure.

Summary

Improvements in the equipment and technique for transseptal left heart catheterization appear to have largely overcome the major problems and complications that have been encountered in recent years with this procedure. Improvements in equipment have included the addition of a stylet for the needle, modifications in the design of the catheter, and the use of a catheter tip occluder both for manipulation of the catheter within the left heart and to close the end hole during selective angiography. The steps employed for insertion of the catheter and needle were described in detail, and the use of landmarks such as the left main-stem bronchus, the spine, the left atrial shadow, and the aortic bulge was discussed. The indications for, and relative contraindications to, transseptal catheterization currently applied in this laboratory were also described. The relative contraindications consist of (1) a giant right atrium, (2) severe rotational anomalies of the heart or great vessels, and kyphoscoliosis; (3) marked dilation of the ascending aorta; (4) anticoagulant therapy, and (5) a history of recent systemic arterial embolization. Since the introduction of these technical changes and precautions, with the exception of one nonfatal aortic puncture, the problems previously encountered during transseptal catheterizations have been avoided in more than 350 consecutive transseptal left heart studies in this laboratory.

References

2. Ross, J., Jr.: Transseptal left heart catheteriza-


