Transseptal Left Heart Catheterization
A Review of 450 Studies and Description of an Improved Technic

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The physician who desires to carry out hemodynamic or angioangiographic studies of the left side of the heart has a large number of technics from which to choose. The ideal method for such investigations should fulfill a number of criteria. First of all, the method must be relatively safe. In order to gain wide acceptance it must be technically simple and individuals trained in the standard catheterization technics should be able to carry it out without difficulty. The procedure should consistently provide access to both the left atrium and the left ventricle. The investigation should not be associated with undue discomfort for the patient and it should be possible to make measurements over prolonged periods of time with the patient in a basal state. The technic should possess sufficient flexibility to be applicable in all age groups and in patients without cardiovascular disease as well as in those with limited cardiovascular reserve. It should be possible to combine the technic with catheterization of the right side of the heart whenever necessary. Finally, the ideal method of left heart catheterization should also allow injection of contrast material into both the left atrium and the left ventricle for selective angiography and should permit sampling of blood or of indicator substances in these chambers. As a result of experiences at the National Heart Institute with a variety of methods for measuring pressures in the left side of the heart it is our impression that transseptal left heart catheterization is the procedure that most nearly satisfies these criteria.

The purpose of this report is to review the experiences with transseptal left heart catheterization in 450 studies and to describe the changes in this method that have evolved, with particular emphasis on the equipment and technics currently employed. Our experiences with transseptal left heart catheterization began with the demonstration, in experimental animals, that the intact interatrial septum could be punctured by means of a needle that was passed through a catheter introduced into the right atrium through the femoral vein. When this technic was initially applied to man, a specially constructed needle of relatively small caliber (no. 19 gage) was employed. While the atrium could be consistently entered, left ventricular pressure could not be measured by this technic. Accordingly, a similar needle of large caliber (no. 17-gage thin-wall) was employed in order to permit the passage of a fine plastic catheter through its lumen, into the left atrium, and across the mitral valve into the left ventricle. A detailed description of the equipment, technic, and applications of this method has been presented previously.

Transseptal left heart catheterization, utilizing a no. 17-gage needle and fine polyethylene catheter, provides many advantages over previous methods of left heart catheterization and its value was subsequently confirmed in other laboratories. Critical evaluation of this approach following our experiences with 294 studies suggested that the technic could be further improved in order to extend its usefulness. Although there were no deaths in this series, the aorta was inadvertently punctured on three occasions. One patient suffered chest pain for several days following the catheterization and developed a small pleural effusion, which cleared spontaneously.

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Another patient required pericardiocentesis when hypotension occurred shortly after puncture of the aorta. Following transfusion he recovered without further therapy and subsequently underwent a mitral commissurotomy. The third patient had no symptoms or change in vital signs. Singleton and Scherlis have also reported a puncture of the aorta without subsequent complications. Although the left ventricle could be catheterized blindly in about 75 per cent of the procedures, this was frequently not possible in patients with pure mitral regurgitation or in those with mixed mitral valve lesions. Although it was possible to inject contrast medium through a modified transseptal needle into the left atrium, the dye could not be introduced with sufficient rapidity to provide angiograms of high quality consistently, and selective left ventricular injections could not be made. Finally, ligation of the right saphenous vein following the procedure limited the number of such studies possible in any given patient. Accordingly, the technic was modified in an attempt to obviate these limitations, and subsequently similar modifications have been employed successfully by other workers.

**Percutaneous Transseptal Left Heart Catheterization**

**Equipment**

**Catheters**

A flexible coiled spring guide wire, and a needle through which it is introduced into the femoral vein are required for percutaneous introduction of the catheter. A radiopaque polyethylene catheter (Odman-Ledin), 70 cm. in length with an outside diameter of 2.33 mm. and an inside diameter of 1.15 mm. was initially employed. More recently, however, a radiopaque Teflon catheter (outside diameter 2.82 mm., inside diameter 1.70 mm.), has been found to be equally satisfactory. The tip of the catheter is tapered and four small openings are provided in the distal 1.5 cm. A flare at the proximal end of the catheter permits seating of the catheter in the commercially available adapter and stopcock. The distal end of the catheter is shaped with a curvature in order to facilitate its passage into the left ventricle. Since the optimal radius of curvature depends on the size of the left atrium, a selection of four different sized loops is available, ranging from 2.0 to 3.5 cm. in radius. The total curvature is 270 degrees, and the distal 3 cm. of the catheter are straight (fig. 1A). A wire stylet is introduced into the catheter to maintain the curvature between studies. Since right heart catheterization is usually carried out in conjunction with the left heart study, a separate 70-cm. catheter with a suitable curvature for entry into the pulmonary artery is employed.

**Stylet**

A stylet, made of no. 18-gage standard-wall stainless-steel tubing with a stopcock permanently attached to its proximal end is employed to straighten the catheter within the inferior vena cava and thereby facilitate its introduction into the right atrium. The stylet is 0.5 cm. shorter than the catheter and its tip is polished to prevent puncture of the catheter (fig. 1B).

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*Picker X-ray, Cat. No. 17.130-100.
†Picker X-ray, Cat. No. 17-113-70.
††Picker X-ray, Cat. No. 17.891-3.
‡‡Manufactured by Becton-Dickinson and Co., Rutherford, New Jersey.
Transseptal Needle

The needle* employed for puncture of the interatrial septum is 71 cm. in length and similar in general design to that described previously (fig. 1C). The shaft and the initial portion of the curvature are made of no. 18-gage stainless-steel tubing, while the distal 1.5 cm. and tip are constructed of no. 21-gage tubing (fig. 1D). The details of the curvature illustrated are of importance in facilitating puncture of the atrial septum. The tip of the needle has been specially ground and polished in order to minimize the possibility of puncture of the catheter wall (fig. 1E).

Equipment for Infants and Small Children

For percutaneous transseptal left heart catheterization in infants and children up to the age of approximately 7 years, a 55-cm. catheter with an outside diameter of 2.31 mm. and an inside diameter of 1.24 mm. has been employed. The distal curvature is prepared with a radius of 1.5 or 2.0 cm. The stylet is made of no. 19-gage stainless-steel tubing and is 54.4 cm. in length. The transseptal needle is 56 cm. in length; its shaft is constructed of no. 19-gage tubing with the distal end of no. 22-gage tubing.

Technic

In most patients right heart catheterization is carried out prior to left atrial puncture. The technic described by Seldinger and first utilized for transseptal left heart catheterization by Cope is employed for the introduction of the catheter into the femoral vein. A stab wound, 2 to 3 mm. in length, is made over the right femoral vein, just below the inguinal ligament. Following puncture of the femoral vein, the guide wire is inserted through the needle and advanced so that its tip lies approximately 15 cm. above the inguinal ligament. The needle is then withdrawn, the right heart catheter is passed over the guide wire, is inserted into the femoral vein, and advanced several centimeters. The guide wire is then removed and replaced with the stylet. As the catheter and stylet are advanced up the inferior vena cava, it is usually necessary to withdraw the stylet so that its tip lies several centimeters proximal to the tip of the catheter. This maneuver permits the end of the catheter to assume a slight curvature, facilitating its passage into the right atrium. The stylet is then withdrawn and right heart catheterization is carried out in the usual manner.

Upon completion of the right heart catheterization, the coiled spring guide wire is reinserted into the catheter, the catheter is removed over the guide wire and replaced by the left heart catheter. The latter is advanced into the right atrium with the aid of the stylet, which is then withdrawn and replaced by the transseptal needle. The interatrial septum is punctured in the manner described previously (fig. 2A). When the location of the needle tip in the left atrium has been confirmed by recording a typical left atrial pressure pulse or the withdrawal of oxygenated blood, the needle tip is turned from a posteromedial to a medial direction and the catheter is advanced with the needle until the tips of both lie freely within the left atrial cavity (fig. 2B). As the catheter is slipped over the end of the needle, the latter is withdrawn to the point of puncture (fig. 2C). With the needle in place, the tip of the catheter is then advanced into the left ventricle and the needle withdrawn (fig. 2D). Passage of the catheter into the left ventricle is facilitated by (1) selection of a catheter with a curvature appropriate for the size of the left atrium, (2) use of the needle to direct the path of the catheter into the proper plane in the anteroposterior direction, and (3) maintaining the catheter in a position as low as possible in the left atrium during the manipulation.

For the simultaneous measurement of left atrial and left ventricular pressures, an 80-cm. polyethylene no. 50 catheter is introduced through the left heart catheter with the aid of a fine wire stylet. The outside catheter is then withdrawn so that its tip lies within the left atrium, leaving the tip of the polyethylene catheter in the left ventricle. Both pressures are then recorded simultaneously with the aid of a Y-shaped connector (fig. 3), similar in principle to that described by Morrow et al. for use with the needle employed for transbronchial puncture of the left atrium. It may occasionally be possible to advance the polyethylene catheter into the aorta (fig. 4).

Results

A total of 450 transseptal left heart catheterizations has been carried out. Percutaneous transseptal left heart catheterization has been performed on 156 occasions in 144 patients, ranging in age from 1 to 67 years. The left atrium was successfully entered in all but two patients. The left ventricle was catheterized in 143 of the 151 percutaneous studies in which this was attempted (95 per cent). Most of the instances in which the left ventricle could not be entered occurred early in the experience of each of the several staff members performing the procedures. The patients in whom left ventricular catheterization was the most difficult were those with severe mitral stenosis; in those with mitral

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*Manufactured by Becton-Dickinson and Co., Rutherford, New Jersey.
regurgitation, on the other hand, this chamber could be catheterized with relative ease. Following completion of the hemodynamic studies selective left heart angiocardiography was carried out in 33 patients. In 22 patients the injection was made into the ventricle and in 11 subjects into the left atrium.

There has been no mortality in the series and no instance of aortic puncture or cardiac tamponade. Small amounts of blood were found in the pericardial spaces of several patients operated upon following the procedure. Presumably this resulted from inadvertent puncture of the free wall of the right atrium. In one patient the tip of the guide wire broke while in the femoral vein and it was immediately removed in the catheterization laboratory under local anesthesia. Two patients
developed transient atrial fibrillation. Two patients developed transient, unexplained hypotension.

The Kr\textsuperscript{85} inhalation test for the detection of left-to-right shunts\textsuperscript{15} was performed in 10 patients following percutaneous transseptal left heart catheterization. The results were negative in each instance, and there has been no suspicion of a persistent shunt in any patient. The interatrial septum was inspected at postmortem examination in three patients who died during operations carried out several weeks after percutaneous transseptal left heart catheterization. In each instance the site of puncture was completely healed and difficult to identify.

**Discussion**

The percutaneous technic of transseptal left heart catheterization described herein can
Simultaneous left atrial (L. A.) and left ventricular (L. V.) pressures recorded by the transseptal technic in a patient with mitral regurgitation and stenosis.

be successfully applied in patients of all ages and provides a number of additional advantages over the method originally employed.

The use of a transseptal needle with a no. 21 or no. 22-gage tip adds further safety to the method, since it reduces the hazard of bleeding, should the aorta or free wall of the atrium be punctured accidentally. The need for surgical exposure of the saphenous vein has been eliminated, adding to the technical simplicity of the procedure. In addition, since the vein is not ligated, repeated studies can be performed in the same patient when desired. The left atrium can be entered almost routinely except in the patients with marked deformity of the thoracic or lumbar spine, with giant atria, or with severe orthopnea.

The controlled manipulation of the radiopaque catheter permits entry into the left ventricle in nearly all patients, even those with pure mitral regurgitation. The lumen of the catheter is large enough to permit rapid injection of a large quantity of radiopaque dye and allows the sampling of blood and the detection of indicators. The ability to measure pressures in the left atrium or left ventricle after the needle has been removed lessens the discomfort of prolonged hemodynamic studies. The removal of the needle permits standard leg exercise to be carried out. In addition, the hazard of acci-
dentally cutting the fine polyethylene catheter utilized in the earlier technic is also eliminated.

Summary
Experiences with 450 transseptal left heart catheterizations are reviewed. There were no mortalities in this series, and the only significant complication was accidental puncture of the aorta in three patients. The equipment and technic employed in the current method, by which a radiopaque catheter of large caliber is introduced into the left ventricle, are described in detail. The advantages of this modification are outlined.

References
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Circulation. 1962;25:15-21
doi: 10.1161/01.CIR.25.1.15
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
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