Left Heart Catheterization by the Transseptal Route
A Description of the Technic and Its Applications

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LEFT ATRIAL pressure was first recorded in man by Cournand et al. during cardiac catheterization in a patient with an atrial septal defect. Their report in 1947 proved the feasibility of passing a catheter from the right atrium to the left when an interatrial communication was present. When operations for the correction of rheumatic mitral and aortic stenosis were undertaken, the value of preoperative measurements of pressure in the left atrium and left ventricle soon became apparent. In these patients, without intraaortic communications, it was necessary to devise other means of access to the left-sided chambers of the heart. The methods of transbronchial and posterior percutaneous left atrial puncture were found to be practical technics for the measurement of left atrial pressure and each was extended to permit left ventricular and aortic catheterization as well. It was found that left ventricular pressure could also be measured by direct transthoracic puncture of this chamber or by means of a catheter passed into it, in a retrograde fashion, from a peripheral artery. The relative advantages and disadvantages of these various methods of left heart catheterization have recently been presented in detail and experience with them has indicated that none is ideal in all respects.

A cardiac catheter, when introduced from the saphenous vein, can invariably be passed through an interatrial septal defect or patent foramen ovale, if such a communication is present. This course of the catheter suggested the possibility to Dr. Emilio Del Campo, during a visit to the National Heart Institute, that the intact interatrial septum could be crossed in the region of the fossa ovalis and provide another means of access to the left atrium. It appeared to us that this could be accomplished by a suitably curved needle passed through a catheter positioned against the septum. In an experimental study in dogs, left atrial puncture by this technic was found to be simple and without hazard. Transseptal left heart catheterization was then applied in clinical studies and preliminary experiences with it were encouraging. The method has now been employed in 130 patients with various forms of heart disease. The present report describes in detail the instruments employed in transseptal left heart catheterization, the technics of the procedure, and some of its applications in cardiovascular diagnosis and clinical investigation.

Material and Method

Equipment

Shortened Right Heart Catheter

The catheter through which the no. 17-gage transseptal needles are passed is a no. 8 Aorto-catheter (61 cm. in length) having an extruded Nylor core. A removable adapter (Tuohy-Borst) is attached to the proximal end of the catheter. The transseptal needles may vary slightly in length and the catheter should be compared with the transseptal needle with which it is to be used; the proximal end of the catheter is cut so that it is 2 cm. shorter than the needle. The length of the catheter then corresponds to the length of the needle from its tip to a point 2 cm. from the indicator arrow (fig. 1).

A no. 7 Aorto-catheter, 53 cm. in length, may be used in identical fashion with the no. 19-gage transseptal needle used in infants.

Transseptal Needles

The transseptal needle for routine use (fig. 1) is constructed of no. 17-gage thin-walled stainless-steel tubing and is approximately 61 cm. in length. A stopcock is permanently attached to the proximal end and immediately distal to it is a metal arrow mounted so that it points in the same direction as the curvature of the distal end of the needle. The shape of the curve in the needle tip has been found to be important in facilitating septal puncture, and it is reproduced to scale in figure 1. The convex surface of the curve in the needle terminates in the leading edge of the needle point and the opening of the needle thus faces the concave surface. The margins of the opening are carefully polished to avoid shearing of the fine plastic catheter that is passed through it.

The transseptal needle employed for angiocardiography with selective injection into the left atrium, is identical to that described above except for its distal end, which has been modified in order to prevent recoil during injection of contrast ma-

*Manufactured by Beeton-Dickinson Co., East Rutherford, New Jersey.

Polyethylene Catheter

A polyethylene catheter 100 cm. in length (Clay-Adams PE 50) with an adapter (Clay-Adams A-2625) at its proximal end is passed through the no. 17-gage transseptal needle for catheterization of the left ventricle and aorta.

Technic of Transseptal Left Heart Catheterization

The patient is prepared by fasting and 100 mg. of pentobarbital are given by mouth 1 hour before the procedure. After local infiltration with 1 per cent Xylocaine, a transverse incision, 3 cm. in length, is made approximately 1 inch below the right inguinal ligament and medial to the pulsation of the femoral artery. With use of a small self-retaining retractor to aid exposure, the saphenous vein is isolated below its junction with the femoral vein. The saphenous vein is ligated distally, and a loose ligature is placed proximally to prevent bleeding from above. When the right saphenous vein has been ligated at a previous time, it is often possible to pass the catheter through the proximal segment or one of the major saphenous branches. If no patent vein can be found on the right, the left saphenous vein is then employed. When the approach is made from the left groin, passage of the catheter and needle sometimes results in abdominal or lower back pain due to traction on the inferior vena cava; this may be minimized by bending the trunk to the right in order to straighten the course of the catheter and needle.

Right heart catheterization is first carried out with a standard catheter. The use of a rotating adapter between the cardiac catheter and the connecting tubing that leads to the pressure transducer facilitates upward rotation of the curved tip of the catheter from the right ventricular apex toward the outflow tract and pulmonary artery. Upon the completion of right heart catheterization the standard catheter is withdrawn.

Before performing transseptal left atrial puncture, the short no. 8 catheter is inspected. The adapter is removed and the transseptal needle is fully inserted. Unobstructed passage of the needle through the catheter is thus assured, and excessive protrusion of the needle tip beyond the recommended 2 cm. may be detected. Following removal of the needle, replacement of the adapter, and attachment of a stopcock, the catheter is inserted.

*Manufactured by Beeton-Dickinson Co., East Rutherford, New Jersey.
into the vein and advanced so that its tip lies in the mid portion of the right atrium (fig. 2A). The adapter is then removed, and the transseptal needle is inserted and gradually advanced. As the needle approaches the junction of the saphenous and femoral veins the curvature is directed posteriorly. It is important to permit the needle to rotate within the lumen of the catheter as it is advanced beyond this area. Free rotation of the needle will occur as it is gently pushed upward. In order to avoid perforation of the wall of the catheter excessive force must not be employed when advancing the needle. If an obstruction to passage of the needle is encountered, it may often be circumvented by manipulating the catheter and needle together beyond the site of obstruction. The needle is advanced until its point lies just within the tip of the catheter in the right atrium. With the aid of the fluoroscope, the catheter tip is then positioned at the junction of the lower and middle thirds of the right atrial silhouette. With one finger placed on the point of the indicator at the proximal end of the needle, the catheter tip is directed posteromedially at an angle of approximately 45° from the horizontal plane (fig. 2B). In the presence of an enlarged left atrium the resistance offered by the bulging interatrial septum may often be felt upon completion of this maneuver. When this resistance is not encountered, alternately advancing and withdrawing the catheter will frequently result in contact with the atrial septum. The site chosen for puncture should be visualized fluoroscopically; in order to avoid the ascending aorta it should be within the lower half of the right atrial silhouette. The transseptal needle is now attached to a pressure transducer by means of a flexible connecting tube. With the catheter held stationary in one hand, and with the indicator arrow of the needle maintained at the 45° angle

Figure 2
A. Roentgenogram demonstrating the proper position of the catheter in the right atrium prior to insertion of the transseptal needle. B. The transseptal needle has been advanced so that its tip lies just within the cardiac catheter and the indicator arrow attached to the needle hub has been rotated posteromedially so that the catheter tip impinges on the interatrial septum. C. The needle has been advanced beyond the catheter tip, thereby puncturing the septum.
with the other hand, the needle is pushed forward the remaining 2 cm. A sudden decrease in resistance is usually appreciated as the needle perforates the septum and enters the left atrium (fig. 2C). The atrial pressure pulse is observed on the monitoring oscilloscope and identified as left atrial in origin by comparison with the previously observed right atrial pressure. In addition, the free withdrawal of oxygenated blood should be possible. Frequently, penetration of the septum is initially incomplete and a high, nonphasic pressure is observed. In this situation the puncture may be completed by advancing the protruded needle and catheter together, approximately 1 cm., until the septum is pierced.

After left atrial pressure has been recorded the polyethylene catheter is advanced through the transseptal needle into the left atrium. The pressure recorded from the tip of the catheter is monitored continuously on an oscilloscopic screen as the catheter is slowly advanced and withdrawn until left ventricular pressure is recorded. It is sometimes helpful to rotate the indicator arrow of the needle to a more horizontal or vertical position in order to modify the initial direction of the polyethylene catheter. Occasionally the catheter may also be manipulated from the left ventricle across the aortic valve into the aorta. When desired, the hemodynamic effects of exercise may be studied by means of a bicycle ergometer pedaled with one leg.

Upon completion of the procedure the polyethylene catheter is first withdrawn, then the needle is removed slowly with the catheter still in place. Finally, the Aorto-catheter is removed, and the saphenous vein is ligated.

**Figure 3**
Left ventricular end-diastolic pressure and measurements of cardiac output obtained during the course of transseptal left heart catheterization in patient P. A. with rheumatic heart disease and mitral stenosis. Ouabain, 0.5 mg., was injected at the time indicated by the vertical arrows.

**Figure 4**
Hemodynamic observations before (left) and after (right) the infusion of 1,500 ml. of whole blood into a human subject. The upper panels are dye-dilution curves for the measurement of cardiac output. On the lower panels the left ventricular (LV), brachial artery (BA), and intra-esophageal balloon (EB) pressure pulses are reproduced.

**Results**
Transseptal left atrial puncture has been performed successfully in 130 patients at the National Heart Institute. There has been no death and no significant complication. Puncture of the free wall of either atrium or of any structure other than the atrial septum has not occurred to our knowledge in any instance. No intrapericardial bleeding has been evident clinically or at subsequent operation. Nitrous oxide tests for the detection of left-to-right shunts were performed before and after transseptal puncture in 10 patients and all tests were negative. The atrial septum could not be punctured in several patients, most of whom had gross enlargement of the right atrium. In these patients displacement of the inferior vena cava and septum prevented contact of the needle with the septal wall. In 2 patients whose hearts were studied at postmortem examination, 5 days and 4 weeks following atrial puncture, pinpoint holes covered by minute white thrombi were found in the region of the foramen ovale. Occasionally one or two atrial premature contractions may be observed at the time of transseptal puncture. No serious or prolonged
Arrhythmias have occurred, however. There has been little or no discomfort, although in a few instances the patients have reported a brief sensation of fullness in the mediastinum and neck during septal puncture.

In the early experience with transseptal left heart catheterization, left ventricular catheterization was not attempted systematically, but the left ventricle has been entered in 40 of the last 50 patients (80 per cent). Failure to catheterize the left ventricle has usually occurred in patients with gross mitral regurgitation. When it was deemed necessary, anterior percutaneous left ventricular puncture was carried out and simultaneous left atrial and ventricular pressures were recorded. Difficulty in advancing the catheter freely within the left atrium occurred in several patients subsequently demonstrated at operation to have large thrombi within this chamber.

Applications of Transseptal Left Heart Catheterization

This method of left heart catheterization has been applied in two general areas of hemodynamic investigation. Increasing evidence of the safety of the transseptal approach has prompted its use in several physiologic and pharmacologic studies of the dynamics of the left side of the heart carried out in the course of catheterization. Since the patient experiences no discomfort, measurements of left heart pressures and cardiac output may be made over a long period of time with the patient in a steady and basal state. For example, the effect on left ventricular end-diastolic pressure and cardiac output of digitalization with a rapidly acting glycose has been studied in a variety of patients (fig. 3). The applicability of Starling's law of the heart to the circulation of intact human subjects is also under investigation. The effects of acutely induced hypervolemia on effective ventricular end-diastolic pressure and cardiac output has permitted the construction of left ventricular function curves in man (fig. 4). During studies of this type left ventricular pressure measurements have been carried out for periods in excess of 2 hours.

Transseptal left heart catheterization has been found equally useful in diagnostic studies and the availability of this technic has broadened the indications for diagnostic left heart catheterization. In patients with valvular heart disease the usual recordings of the left atrial pressure pulse and of the pressure gradient across both the mitral and aortic valves may be readily obtained both at rest and during exercise. Representative

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Pressure pulses recorded as the polyethylene catheter was withdrawn from the aorta across the aortic valve, through the left ventricular outflow tract and into the main cavity of the left ventricle (LV). There is a moderate pressure gradient between the main cavity of the left ventricle and the left ventricular outflow tract. BA refers to the simultaneously recorded brachial artery pressure pulse.

Pressure pulse recorded from the left atrium (LA) of a 2-year-old child with a ventricular septal defect and intact interatrial septum. The prominent "v" wave is related to increased filling of the left atrium during ventricular systole. Tracings of this type are reproduced in figures 5 to 7. Measurements of cardiac output by the indicator-dilution technic with left heart injection are also conveniently performed in the course of these studies.

The transseptal route has been found to be particularly applicable for left heart catheterization in children. Experience so far indicates that the smaller size of the heart does not render the technic more difficult. General anesthesia has been required only in infants. The ease with which left heart catheterization may now be performed in children has permitted its use in the study of patients...
with congenital heart disease and intact atrial septa (fig. 8). Injections of indicator dye or of solutions of radioactive krypton into the left atrium and ventricle have facilitated the localization of the site of origin of left-to-right shunts (fig. 9).

Recently, the transseptal technic has been extended to permit selective angiocardiography with left atrial injection. It is anticipated that this approach will be found increasingly useful when visualization of the detailed anatomy of the chambers and valves of the left side of the heart is required (fig. 10).

Comments

Although final evaluation of transseptal left heart catheterization must be reserved until a larger number of patients has been studied, the superiority of the method is suggested by the experience to date. Of greatest importance would seem to be its safety. The intravascular route of the needle avoids the hazards attendant upon external puncture; pneumothorax, hemothorax, cardiac tamponade, and unexplained hypotension have thus been obviated. It is conceivable, however, that improper use of the transseptal needle could result in puncture of the aorta, the free wall of the right atrium, or of the coronary sinus. It is important, therefore, that the operator be well acquainted with the detailed relation of these structures to the atrial septum; before the procedure was undertaken in this clinic it had been utilized extensively both in dogs and in cadavers. Furthermore, the chest roentgenogram of each patient should be studied before catheterization in order that the position of the aorta, the size of the atria, and any anomalies of position or rotation of the heart be known. When these precautions are observed, the procedure is technically simple and can be performed by anyone trained in the usual right heart catheterization technics. The participation or immediate availability of a thoracic surgeon or endoscopist is therefore not mandatory.

Another advantage of transseptal left heart catheterization is the ease with which it may be combined with right heart catheterization; both procedures are performed through a single venous intubation. Furthermore, when the need for left heart catheterization or left atrial angiocardiography becomes apparent in the course of right heart studies, transseptal left atrial puncture may be performed forthwith. For this reason, the right saphenous vein is now used for right heart catheterization in many patients.
The procedure results in no more discomfort to the patient than an ordinary right heart catheterization and in this respect is clearly preferable to the posterior percutaneous and transbronchial methods of left atrial puncture. The disadvantages of the latter technic in the study of children are well recognized and transseptal left heart catheterization is certainly the method of choice in this age group. Its increasing use in patients with congenital heart disease is anticipated.

Finally, it appears that catheterization of the left ventricle with the fine polyethylene catheter passed through the transseptal needle is accomplished as readily as with other methods of left atrial puncture. When the left ventricle cannot be entered, the supine position readily permits anterior percutaneous puncture of the left ventricle, a procedure not easily accomplished with the patient in the prone position required for posterior percutaneous left atrial puncture.

Summary

Experiences with left heart catheterization by the transseptal route in 130 patients are presented. The instruments and technics employed are described in detail and some of the applications in diagnosis and clinical investigation of the method are illustrated. The advantages of transseptal left heart catheterization, which indicate its superiority over other technics, are discussed.

Summario in Interlingua

Es presentate experientias in catheterismo sinistrocardice a accesso transseptale in 130 patientes. Le instrumentos e le technicas usate es describite in detale, e certes del applications in le dianostica e le investigation clinica es illustrate. Le avantages es discutite que inhere in transseptal catheterismo sinistrocardice in comparation con altere technicas.

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