Left Heart Catheterization by the Transbronchial Route

Technic and Applications in Physiologic and Diagnostic Investigations

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Left heart catheterization is proving of increasing importance in the study of a variety of congenital and acquired cardiovascular defects. More than 500 left heart catheterizations have been performed by the transbronchial method without death or serious sequelae. This technic and its usefulness in clinical investigation and in the assessment of valvular heart disease are described.

The development and application of technics for catheterization of the left side of the heart are proving of increasing importance in the study of patients with many types of cardiovascular disease. Two methods of left atrial puncture are commonly employed. The transbronchial method, devised by Allison and Linden and Faquet et al. and the posterior percutaneous route employed first by Bjork et al. Since 1953 more than 500 transbronchial left heart catheterizations have been performed at the National Heart Institute where the technic has been extended to permit the passage of a catheter into the left ventricle. The present report summarizes our experience with the method and the details of technic and instrumentation that have evolved.

Anatomic Considerations

When the left atrium is of normal size, as in many forms of congenital heart disease and in most patients with isolated aortic valve disease, it lies below and anterior to the carina and main bronchi. The space between the carina and left atrium is occupied only by mediastinal fat and areolar tissue. Irrespective of the degree of left atrial enlargement, the portion of the atrium adjacent to the left bronchus is, in most instances, extrapericardial. The anatomic relations of the normal-sized left atrium to the bronchial tree are shown in figure 1. As the left atrium enlarges, as in mitral valvular disease, it extends in a posterior and superior direction and may come in contact with or even elevate and compress the left main bronchus. The altered relationships of the left atrium to the bronchi in mitral valve disease are illustrated in figure 2.

Equipment and Instrumentation

A standard 7- or 8-mm. bronchoscope is used in adult patients. The transbronchial needle will pass through a 5-mm. full-lumen bronchoscope and an instrument of this size is used in children.

The needle used for bronchoscopic catheterization is illustrated schematically in figure 3. It consists of an outer tube of stainless steel tubing 4.5 mm. in outside diameter and 50 cm. long, which divides proximally into 2 limbs, each fitted with a female Luer connector. The needle itself is constructed of 17-gage stainless steel tubing and a sleeve 6 cm. from its tip threads into the distal end of the outer tube. The needle point is ground to a 45° bevel and the edges are carefully smoothed to prevent the catheter from being caught or cut. The portion of the needle projecting from the outer tube represents the effective penetrating length of the needle. A safety collar is soldered to the needle just distal to its connection with the outer tube. The remainder of the needle, when assembled, lies inside the outer tube and its proximal end terminates in a funnel-shaped tip that lies within the upper Luer connector of the outer tube. Holes are placed at intervals along the portion of the needle within the outer tube to permit the evacuation of all air from the space between the outer tube and needle and to allow the transmission of pressure pulses from the needle tip to the outer tube.

Prior to use the needle and outer tube are assembled and the upper proximal limb of the outer tube is closed with a needle plug. The instrument is sterilized by autoclaving it. The lower proximal limb of the outer tube is connected via a 3-way stopcock to a Statham P23A transducer filled with 70 per cent alcohol.

The catheter ordinarily employed is made of poly-

* Manufactured by the Becton-Dickinson Co., Rutherford, N. J.
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Fig. 1. Anatomic relations of the normal-sized left atrium to the main bronchi. The sites of bronchial puncture are indicated.

Fig. 2. Anatomic relations of the enlarged left atrium to the main bronchi.

ethylene. (Clay-Adams, size PE 50, 0.58 mm. I.D., 0.96 mm. O.D.). It is 100 cm. in length and its proximal end is flanged with heat and fitted with a screw adapter (Clay-Adams A-2625), which does not compromise its lumen. It is sterilized by soaking in aqueous benzalkonium chloride 1 per cent. This catheter is attached, via a 3-day stopcock to a Statham P23D transducer. The natural frequency of this catheter-gage system is approximately 20 c.p.s.

Both photographic and direct-writing recorders have been used in these studies. A photographic system has been found preferable because of greater paper width and the advantages of simultaneous superimposed pressure records. The records reproduced were made with a multichannel cathode-ray instrument. A 2-channel oscilloscope is used for visual monitoring of the electrocardiogram and pressure pulse from the needle or catheter.
PROCEDURE

The patient is prepared for the procedure by fasting for 6 hours. Intramuscular penicillin is given the evening before the catheterization and injections are repeated the following 2 mornings. Demerol, scopolamine, and an oral barbiturate are given 40 to 60 minutes beforehand. The larynx and trachea are anesthetized by the injection of 3 ml. of 1 per cent tetracaine hydrochloride (Pontocaine) through the cricothyroid membrane. Additional anesthetic is then sprayed into the hypopharynx. Electrocardiographic electrodes and a phonocardiograph microphone are attached to the patient.

All air is expelled by flushing the needle and outer tube with 30 to 40 ml. of sterile heparinized saline solution injected through the stopcock. The assembly is then clamped with the fluid-filled needle horizontal and in communication with the transducer. The transducer is then balanced. A convenient sensitivity setting has been found to be 2 mm. of paper deflection per mm. Hg pressure.

The bronchoscope is introduced, advanced to the carina, and additional Pontocaine is sprayed into the first portion of the left bronchus. In most instances a point on the anterior wall of the left bronchus 1 to 2 cm. from the carina is selected for puncture. If the left atrium is of normal size, a conscious effort must be made to direct the needle as far anteriorly as possible. This is facilitated by rotation of the bronchoscope so that its bevel lies posteriorly. The saline filled needle is then introduced into the bronchoscope, the transducer serving as a convenient handle. A zero or baseline pressure tracing is recorded before the needle pierces the bronchial mucosa and while it is in the axis of its eventual penetration. This baseline remains valid if the angle of the needle to the horizontal remains unchanged. The needle is then inserted through the bronchus for its full length and its entry into the left atrium can usually be felt as a sudden lessening of resistance. The needle is immediately irrigated with sterile saline solution and the left atrial pressure curve ordinarily appears immediately upon the monitoring oscilloscope. If the puncture is unsuccessful it is usually because the needle was not directed far enough anteriorly. It is withdrawn, irrigated, and inserted again after the baseline has again been recorded.

Left atrial pressure is recorded during several respiratory cycles and during a period of apnea in midinspiration. Mean pressure is determined by electric damping or by planimetric integration of the curves.

After left atrial pressure has been recorded via the needle, the catheter is filled with heparinized saline and its tip held at the level of the midaxillary line where the zero or baseline pressure is recorded. The catheter is handled by a gloved assistant to maintain sterility. The needle plug is then removed by the endoscopist and the assistant passes the catheter into the proximal end of the needle. The catheter is advanced by the assistant for about 50 cm. and it is then handled by the ungloved endoscopist. Thus, the portion of the catheter that enters the heart remains sterile. The pressure at the catheter tip is monitored by an oscilloscope, the face of which is visible to the endoscopist. The catheter is slowly advanced into the atrium and occasionally irrigated with saline. When the mitral leaflets are mobile their movement can often be felt on the catheter tip just before it enters the ventricle. The entrance of the catheter into the ventricle is signaled by a change in the oscilloscopic tracing from an atrial to a ventricular pressure pulse. A record of ventricular pressure is made and recording is continued as the catheter tip is slowly withdrawn into the left atrium. Catheterization of the ventricle and pull-out tracings are usually repeated several times after which the catheter is withdrawn, the needle plug reinserted, and the needle removed. The puncture site is inspected, residual mucus and blood aspirated, and the bronchoscope withdrawn.

Ordinarily, no difficulty is encountered in passing the catheter across the mitral valve. An exception is the presence of gross mitral insufficiency when the catheter may enter the ventricle only to be washed
back into the atrium with ventricular systole. A stiffer catheter of extruded Nylon may then be substituted for the flexible polyethylene one.

In our patients an attempt has been made to pass the catheter from the left ventricle into the aorta only in congenital aortic stenosis where a subvalvular obstruction may exist. Ordinarily, the aortic valve gradient is determined by simultaneous measurement of brachial artery or central aortic pressure while the transbronchial catheter is in the left ventricle. The details of central aortic catheterization are described elsewhere.5

RESULTS

Transbronchial puncture of the left atrium has been performed more than 500 times in patients with congenital or acquired heart disease. The procedure was also carried out in 15 patients with normal hearts undergoing bronchoscopy for other reasons. In 4 patients abnormalities of the mouth or jaw prevented introduction of the bronchoscope. In an occasional patient with a left atrium of normal size the puncture was unsuccessful. There were no deaths in the series. There have been no instances of infection, pneumothorax, mediastinal emphysema, or pericardial tamponade. In many patients the sputum was blood-streaked for several hours following the procedure but there was never significant hemoptysis. No difficulty has been encountered with withdrawal of the catheter through the needle and the catheter was never cut. In some of the patients undergoing operation after the procedure the pericardial fluid was found to be xanthochromic or blood-stained. In none of these was the pericardial fluid increased in quantity or under pressure. The bronchoscopy and catheterization can usually be completed in 5 to 10 minutes although in selected patients continuous records have been made for 45 minutes or longer.

In this clinic, left heart catheterization is employed in 2 general areas of investigation. The first of these is concerned with the study of a variety of clinical hemodynamic problems.

**Fig. 4** Top. Simultaneous left and right ventricular pressure pulses in a patient with the electrocardiographic configuration of complete left bundle-branch block. The onset of ventricular contraction is indicated. Contrary to expectation there is no delay in the onset of left ventricular contraction.

**Fig. 5** Middle. Indicator dilution curves recorded from the femoral artery following left atrial and left ventricular injections in a patient with an interatrial septal defect. In the curve resulting from left atrial injection, the fraction of the dye that was shunted across the defect and through the pulmonary circulation interrupts the descending limb of the primary curve. The curve resulting from the left ventricular injection is normal, indicating the absence of a left-to-right shunt distal to a competent mitral valve. Midpoint of injection is indicated by the vertical arrows. Time intervals are 1.0 second.

**Fig. 6** Bottom. Pressures recorded simultaneously from the left atrium, left ventricle, and brachial artery in a patient with combined mitral and aortic stenosis. The stippled area shows the mitral valve filling pressure gradient and the diagonally cross-hatched area the aortic valve gradient. Left atrial pressure was recorded in this instance by a second needle puncture while the catheter remained in the left ventricle.
Among these have been: (1) the determination of the sequence of ventricular contraction in bundle-branch block\(^6\) (fig. 4); (2) the study of pressure-volume relationships in the left atrium\(^7\) and left ventricle\(^8\); (3) the influence of increased central blood volume on left heart filling pressures; (4) the effect of acutely increased peripheral resistance on the left atrial pressure contour in mitral valve disease\(^9\); (5) indicator dilution curves with left heart injection in the precise localization of left-to-right shunts and the detection of mitral and aortic insufficiency\(^10\) (fig. 5).

The second area of usefulness has been the clinical evaluation of patients with valvular heart disease. Attention has been focused upon: (1) the evaluation of the left atrial pressure pulse contour in differentiating mitral stenosis and mitral insufficiency\(^11\); (2) determination of the diastolic gradient across the mitral valve in the selection of patients for mitral commissurotomy and in the assessment of the hemodynamic results of the operation (fig. 6); (3) measurement of the systolic gradient across the aortic valve in the selection and postoperative evaluation of patients with aortic stenosis (fig. 6); (4) determination of the hemodynamically predominant lesion in patients with combined valvular lesions.

**Discussion**

Perhaps the most essential requirement for successful transbronchial left heart catheterization is the participation of an experienced bronchoscopist. Good topical anesthesia and a smooth introduction of the instrument are mandatory. The procedure has been carried out even in severely ill patients when careful attention has been directed to their general preparation and the timing and dosage of preanesthetic drugs. The presence of severe tachycardia or frequent ventricular extrasystoles has usually constituted a contraindication to the procedure. The method lends itself well to serial studies in the same patient. Numerous patients have been catheterized 3 or more times and 1 individual has had 7 transbronchial left heart catheterizations.

When the decision is made to employ any procedure extensively in clinical investigation first consideration must be given to its safety. In this regard, some comparison of the transbronchial and percutaneous methods of left heart catheterization would seem in order. Although we have not employed percutaneous puncture of the left atrium, that method has been widely adopted in this country. Bjork and colleagues\(^12\) have recently reported their experiences with percutaneous left heart catheterization in 167 patients. Of these, 39 also had angiocardiographic examinations with left heart injections. There was a total of 14 major complications. Of 2 patients who developed cardiac tamponade, 1 died. Cardiotomy was required on 2 occasions for removal of a knotted or cut catheter. Bjork therefore concluded that left heart catheterization should be performed only when the information obtained by the procedure was required in making a decision as to operation. Goldberg\(^13\) has performed 450 left heart catheterizations by the percutaneous method. In this series there were 5 deaths. Four patients required cardiotomy for knotted catheters; 5 had significant hemopericardium. There was 1 death resulting from hemopericardium among the 75 percutaneous left heart catheterizations performed by Wood at the Mayo Clinic.\(^14\) In a series of 40 percutaneous left heart catheterizations performed by Blakemore, 1 of 2 patients who developed cardiac tamponade died.\(^15\)

No deaths or significant complications occurred in the course of the 500 transbronchial catheterizations in the present series. Recent communication from Professor Allison,\(^16\) Dr. Facquet,\(^17\) and Mr. Geoffrey Wooler\(^18\) indicate that they have performed transbronchial puncture of the left atrium in 160, 200, and 211 patients respectively. No death or serious complication occurred in any of these series. Thus, in a combined experience of over 1,000 transbronchial left heart catheterizations in 3 clinics, the procedure has never resulted in death or serious sequelae.

In transbronchial puncture of the left atrium the needle does not ordinarily traverse the free pericardial space. This is thought to account in large measure for the absence of complications due to intrapericardial bleeding and tamponade. In paravertebral puncture of the left
atrium the needle must pass through the free pericardium and in relation to the lung, aorta, azygos vein, and esophagus. Although a small pneumothorax or hemothorax is of little importance ordinarily, either would seem undesirable in a patient ill with heart disease. As the safety of the transbronchial method has become progressively apparent we have felt justified in using the technic as a clinical investigative tool.

With a bronchoscope in the trachea most patients cannot be considered to be in a steady basal state, and valid measurement of the cardiac output cannot be made by the direct Fick method. Also, during bronchoscopy studies involving exercise are impractical. These objections to the transbronchial method have been largely obviated. Cardiac output is determined at the time of bronchoscopy by the indicator dilution method. The validity of the technic and instrumentation employed had been previously established. Hemodynamic observations are made with the bronchoscope in place, after which the needle and bronchoscope are withdrawn and the catheter is left in the atrium or ventricle. Measurements of pressures and cardiac output are then repeated after the patient has returned to a more basal state. Although the determination of cardiac output by the Fick method is possible, simultaneously with the measurement of left heart pressures by the percutaneous method, it has not as yet been demonstrated that a basal steady state is readily achieved with this technic.

**SUMMARY**

The technic and instrumentation of left heart catheterization by the transbronchial route are described. More than 500 catheterizations have been performed at the National Heart Institute without mortality or serious morbidity. The procedure has been found useful in a variety of clinical investigations and in the preoperative selection and postoperative assessment of patients with valvular heart disease.

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**SUMMARIO IN INTERLINGUA**

Le technica e instrumentation de catheterisation sinistro-cardia a via transbronchial es describite. Plus que 500 catheterisationes ha essite execute al Instituto National del Corde sin mortalitate e sin serie morbiditate. Le technica se ha proveve utile in un varietate de investigationes clinico e in le selection preoperatori e le evaluation postoperatori de patientes con morbo de valvula cardia.

**REFERENCES**

1 Allison, P. R., and Linden, R. J.: The bronchocoeic measurement of left auricular pressure. Circulation 7: 669, 1953.
9 Braunwald, E., Morrow, A. G., and Welsh, G.


13 Goldberg, H.: Personal communication.


15 Blakemore, W. S.: Personal communication.

16 Allison, P. R.: Personal communication.

17 Facquet, J.: Personal communication.

18 Wooler, G. H.: Personal communication.


The authors present the results of vectocardiographic studies in 13 patients with the Wolff-Parkinson-White syndrome with particular consideration of the anomalous (premature) component of the QRS complex. The respective portion of the ventricular loop has often a complex appearance, not evident in the scalar leads, and points always anteriorly and to the left. Its duration varies between 0.04 and 0.13 second. If the entire thorax is explored by unipolar (scalar) leads, mirror-image patterns of the abnormal deflection can be obtained in diametrically opposed chest positions. The authors conclude on the basis of this analysis that the preexcitation component corresponds to forces different from the normal initial forces and that they occur in a limited and well-defined area, remote from normal conduction pathways. The point of origin seems to be somewhere near the electric center of the heart, rather than in some peripheral portion of the ventricular myocardium.

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