Transseptal Left Heart Catheterization
An Analysis of 390 Studies*

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A number of technics for left heart catheterization have been employed in the past decade.1 Transseptal left heart catheterization2-5 has emerged as the most physiologic approach toward recording of left atrial and left ventricular dynamics. About 1800 physiologic catheterization'' has emerged as the most septal of the procedure.

In the past decade, systematic arterial cannulation were performed. Right heart puncture was affected via standard transseptal techniques, utilizing a 17 T Ross needle and a number 8 Lehman catheter with right saphenous vein cutdown. In the remaining 325 transseptal studies, the approach described by Brockenbrough et al.4 was employed. The Ross technique is no longer utilized. In adults, the Brockenbrough transeptal needle is made to a length of 78 cm.; the shaft is constructed of 18 gauge stainless steel tubing while the distal 1.5 cm. tip is made of 20 gauge steel tubing. In children to age 10, 19 and 21 gauge tubing are employed respectively; the total length is 55.5 cm., of which the distal 1 cm. is 21 gauge. Radiopaque Teflon catheters** are used. These are 76 cm. long for adults, with a tapered tip opening large enough to accommodate a flexible coiled spring wire 0.045" in diameter. In children, the corresponding catheter measurements are 54 cm., with a tip opening into which a guide wire 0.035" in diameter would fit. Four side openings are added to the catheter tips. Initially several size catheter tip curvatures (2.0 to 3.5 cm. in radius) were employed for adults. We soon found that the best results were obtained with tip curvature of 2.0 cm. in adults and 1.5 cm. in children, even in patients with large left atria. The spring guide and Teflon catheters are inserted percutaneously into the right femoral vein using the Seldinger technique.9 In the vast majority of patients, the guide wire and Teflon catheter are readily passed into the right atrium; the straight stainless steel stylet is rarely needed.

Entrance into the left atrium is gained by puncture of the atrial septum with a Ross needle (in 65 cases) or a Brockenbrough needle (in 325 studies). The septum is punctured at a level corresponding to the junction of the middle and lower thirds of the right atrial border. When the Ross needle was used, access to the left ventricle was provided by a fine polyethylene non-radiopaque catheter,† 110 cm. long, passed through the Ross needle into the left atrium. When the Brockenbrough needle is employed, the Teflon catheter and...

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needle are advanced together after the needle atrial septal puncture. When the Teflon catheter is well within the atrial cavity, the transseptal needle is withdrawn completely and the catheter passed into the left ventricle. In selected cases (mitral prosthetic valve implantation, or a history of systemic arterial embolization, or inability to pass a catheter through the mitral valve), left ventricular pressures are recorded by percutaneous retrograde femoral artery catheterization.

Certain precautions are routinely observed before femoral vein puncture. The transseptal needle is passed into the Teflon catheter in vitro to verify that the needle is about 1.5 to 2 cm. longer than the catheter, in adults, and that the entire 1.5 cm. needle tip protrudes beyond the catheter tip when the needle is fully inserted in the Teflon catheter. The strength of the union of the 18 and 20 gauge portions of the transseptal needle is tested to be certain that the two portions of the needle would not be separated in vivo. This complication has been reported, in vitro separation of the two portions of the needle occurred once early in our experience. In addition, the entire transseptal needle is inspected as it lies on the table top to make certain that the needle tip and the arrow indicator at the other end of the needle are in the same plane. If they are not, puncture of the free wall of the right atrium or of the ascending aorta may complicate attempted atrial septal puncture. At least two transseptal Brockenbrough needles have been defective in this aspect and been returned to the manufacturer.

During recording of right atrial pressures through the transseptal needle within the Teflon catheter, the needle is advanced to engage the atrial septum while the distal arrow indicator is held firmly in a 45° left posterior position. The atrial curve becomes flat and devoid of oscillation when the needle tip engages the atrial septum. Atrial premature beats may develop at this point. As the needle is advanced further, a "giving" sensation is felt as the left atrium is entered and left atrial pressures are recorded. The sensation of "give" is similar to that experienced during a lumbar puncture. It is our firm belief that transseptal puncture should only be done with such pressure recording and should never be done without pressure control. The double contour of the left atrial border within the right atrial shadow is readily seen when a fluoroscopic image amplifier is utilized (especially if the left atrium is enlarged) and serves as a guide to the preferred site of atrial septal puncture. The puncture site is kept as low as possible to facilitate subsequent passage of the Teflon catheter into the left ventricle. Passage of the catheter tip through the mitral valve is considerably more difficult after a relatively high atrial septal puncture—and in addition the danger of puncture of the ascending aorta within the pericardial cavity is increased. After needle atrial septal puncture, the needle and Teflon catheter are grasped firmly and advanced to pass the catheter itself into the left atrium. The "snapping" of the needle tip at this point, as described by Aldridge, has not been a problem if the needle and catheter are advanced together, and if the tip of the Teflon catheter is not frayed by previous use. If the left atrium is small, the left atrial pressure curve may become damped as both needle and catheter are advanced. This is a danger signal to us and means that the needle tip has engaged the posterior wall of the left atrium with the consequent possibility of perforation of the free posterior wall of the left atrium. The needle and catheter are therefore withdrawn if the left atrial curves become damped and an atrial septal puncture at a point lower than the previous site is then done. In no case has this approach failed to permit advancement of the catheter over the needle into the left atrium, provided of course that the needle tip itself has successfully entered the left atrial cavity. Atrial septal penetration by the catheter without needle puncture has not been feasible in our hands to date.

After the Teflon catheter tip is advanced
together with the transseptal needle into the left atrial cavity, the catheter is passed over the needle tip further into the left atrium. The transseptal needle is then completely withdrawn. It has been our experience that the catheter tip has usually found its way into a branch of the left upper lobe pulmonary vein at this point. Advancement of the catheter tip results in passage of the tip outside the cardiac shadow or results in a damped atrial pressure curve. To negotiate the catheter tip into the left ventricle, it is necessary to withdraw the catheter tip slowly under careful fluoroscopic control. The catheter tip will suddenly descend 1.5 to 2 cm. within the cardiac shadow as it is withdrawn. At this point the tip is disengaged from the entrance of the pulmonary vein and lies free in the atrial cavity and may usually readily be passed into the left ventricle. If passage through the mitral valve proves to be troublesome after five minutes of fluoroscopic manipulation, several techniques may be utilized. The transseptal needle may be re-inserted into the Teflon catheter and advanced approximately to the site of atrial septal puncture. The arrow indicator is rotated to a left horizontal or left anterior position and the catheter tip manipulated into the left ventricle by movement of the proximal end of the transseptal needle. Alternatively, the coiled spring guide wire may be passed through the Teflon catheter into the left atrium and left ventricle. Entrance into the latter chamber is usually heralded by the development of ventricular premature beats. The Teflon catheter may then be passed over the coiled guide wire tip into the cavity of the left ventricle and the guide wire completely withdrawn. A third approach is to pass a 110 cm. white non-radiopaque Teflon catheter through the larger Teflon catheter into the left atrium and left ventricle under pressure control. The larger catheter is then passed over the smaller Teflon catheter into the left ventricle and the latter catheter completely withdrawn. All of these procedures may on occasion fail. Under these circumstances 5 to 10 ml. of contrast material is rapidly injected by hand into the left atrium through the radiopaque Teflon catheter. This sequence is recorded on video tape with a Sony tape recorder. This procedure permits visual localization of the exact site of the mitral valve and has on occasion permitted left ventricular catheterization which was not previously possible.

Several other points should be mentioned. If there is a documented history of systemic arterial embolization, manipulation of the transseptal needle and the radiopaque Teflon catheter within the left atrial cavity are kept to a minimum. If registration of left atrial pressure curves is deemed necessary, then either transseptal puncture with the Brockenbrough needle alone is performed, or the Teflon catheter is passed over the needle as described above and left atrial pressures recorded through the catheter. The latter is not manipulated within the left atrial chamber for either left ventricular catheterization or for injection of radiopaque material into the left atrial cavity. If contrast visualization of the left atrium is necessary, pulmonary artery injection is utilized under these circumstances. On at least two occasions, attempted transseptal puncture with the Brockenbrough needle resulted in recording of flat non-oscillating curves from within what was apparently the left atrium. A history of systemic arterial embolization had not been obtained in either subject. Repeat puncture led to similar results. The procedure was then terminated without complication with the realization of the probability that the transseptal needle had entered a thrombotic mass in the left atrial cavity. This impression was verified at surgery in both cases. Knowledge of this potential problem in left atrial puncture is of considerable importance in prevention of complicating systemic arterial embolization.

Calcification of the left atrial wall within the right atrial shadow was encountered in several instances. Uncomplicated transseptal passage of both needle and catheter was readily performed in these patients. Severe
left atrial enlargement has not made transseptal puncture more troublesome. Extreme right atrial enlargement has been reported to make transseptal puncture more difficult by inability to engage the transseptal needle on the atrial septum; such extreme degrees of right atrial enlargement have not been encountered in our series. The exact curvature of the distal 20 gauge tip of the Brockenbrough needle varies. In some patients, it may be difficult or impossible to engage and puncture the atrial septum with one particular needle. If this difficulty is encountered after several tries, we routinely change needles and have most often completed left atrial puncture with the second needle without any difficulty.

**Subjects**

Most patients had rheumatic heart disease. Mitral stenosis or mitral stenosis and insufficiency was most commonly encountered. Aortic valve disease, either stenosis, insufficiency or both, was frequently also present, with or without mitral valve disease. Dilatation of the ascending aorta with aortic insufficiency did not make transseptal puncture more difficult. Ventricular septal defect was present in six subjects. Thirty-two were found to be free of detectable heart disease after complete right and left heart study. The facility and safety with which transseptal left atrial puncture may be performed has permitted us to utilize this procedure under a wide range of circumstances and patient material. It is our conviction that complications may be expected most frequently in only seriously ill patients and those with atrial thrombi or history of systemic arterial embolization. The risk of transseptal puncture in the well compensated cardiac should be little if at all different from the risk of right heart catheterization alone. Utilization of the Brockenbrough needle with a 20 gauge tip materially reduces the risk resulting from aortic puncture as compared to use of the 17 or 16 gauge Ross needle. The percutaneous right femoral vein approach (we have had no experience with use of the left femoral vein) has permitted as many as three to four left atrial catheterizations in the same patient. In theory, many multiple left heart studies should be possible with this technique.

The age of our patients has varied from 6 to 74 years. Other workers have studied patients in the first decade of life without difficulty. Brockenbrough et al. have reported 63 successful studies in 65 children, ages 12 months to 12 years, without significant complication. Both the Ross and Brockenbrough percutaneous approaches were utilized in the latter study. Roveti et al. utilized Ross transseptal left atrial puncture technique in 20 children, age 18 months to 16 years. The left atrium was entered in 85 per cent and the left ventricle in 70 per cent of these patients.

**Results**

Three hundred ninety successful left atrial punctures have been performed in this laboratory. The first 65 of these studies were performed with the Ross technique. In two others, the ascending aorta was punctured by the Ross needle without subsequent incident; the procedure was, however, discontinued at this point. In a third subject, the nylon Lehman catheter could not be passed up the inferior vena cava to the right atrium. In a fourth patient, the right saphenous vein was thrombosed. In a fifth, the Ross needle could not be passed into the left atrium from a slightly enlarged right atrium. The left atrium was therefore entered in 65 of 70 attempts, or 93 per cent. In all 65 patients in whom the left atrium was entered, left ventricular catheterization was attempted using a fine non-radiopaque polyethylene catheter, 110 cm. long. In 46 of these 65 individuals (71 per cent) left ventricular catheterization was successful; however, the left ventricular pressure curve was not infrequently damped, resulting in underestimation of mitral diastolic and aortic systolic gradients. No serious complications resulted in this series of transseptal punctures. Superficial
saphenous thrombophlebitis developed two days post-catheterization in one subject.

Three hundred twenty-five successful left atrial punctures were performed with the Brockenbrough needle and catheter. The catheter was advanced over the needle in all cases. In one of this group, the ascending aorta was punctured (by needle only) without incident prior to left atrial puncture. In two subjects neither the spring guide wire nor the Teflon catheter could be passed up the inferior vena cava to the right atrium. In a third patient, two attempts at transseptal atrial puncture resulted only in entrance into the pericardial space; the procedure was therefore discontinued without further incident. In a fourth patient, a six-year-old child, the atrial septum could not be engaged and the left atrium therefore could not be entered. The left atrium was thus punctured in 325 of 329 attempts, or 99 per cent.

In 290 of the 325 studies (89 per cent) the left ventricle was catheterized with the radiopaque Teflon catheter. In 18 studies, the left ventricle could not be catheterized despite repeated prolonged attempts. In 17 catheterizations, left ventricular entrance was not attempted after passage of the radiopaque Teflon catheter into the left atrium. A history of previous systemic arterial embolization or replacement of the mitral valve by a Starr-Edwards prosthetic valve has interdicted left ventricular catheterization in our laboratory. Overall, therefore, the left ventricle was successfully catheterized in 290 of 308 attempts, for a rate of 94 per cent.

Three major complications were attributed to transseptal left heart catheterization in our series. Two patients died, 48 hours, and seven days respectively after study, both of superior mesenteric artery embolization with infarction of the gut. Operative intervention was of temporary benefit in the latter patient who, however, succumbed seven days after catheterization; at post-mortem examination, ruptured corpus luteum was found with two liters of blood in the peritoneal cavity. Anticoagulant therapy after superior mesenteric artery embolectomy and gut resection undoubtedly was a major causative factor in the peritoneal bleeding. The left atrial cavity was free of thrombotic material. In the first patient (died 48 hours after study), a large thrombotic mass filled the left atrial appendage; embolization to the superior mesenteric artery caused infarction of the bowel with the subsequent demise. Cerebral embolization occurred in a third patient who made a complete recovery in seven days. These experiences have caused us to limit catheter manipulation in the left atrial appendage if a history of systemic arterial embolization is present. Transient atrial fibrillation after atrial septal puncture was noted only once.

Transient ventricular fibrillation (lasting one-half to one minute) followed immediately after pulmonary artery, left atrial and left ventricular radiopaque dye injection in three subjects. All three arrhythmias reverted either spontaneously or after direct current countershock without subsequent difficulty. These arrhythmias should properly be considered as complications of angiography, and not as complications of transseptal left heart catheterization.

Morbidity was quite limited in this series. Two patients developed femoral vein phlebitis which cleared after a few days of bed rest. Minor bleeding from the right groin area occurred on rare occasions and was treated by local pressure only.

**DISCUSSION**

This laboratory has had extensive experience with two types of left heart catheterization—the posterior percutaneous left atrial puncture technic, and transseptal left heart catheterization. The former approach has not been employed since 1960. Retrograde left ventricular catheterization is utilized when the mitral valve cannot be traversed (on rare occasions in tight mitral stenosis) or should not be traversed (systemic arterial embolization or Starr-Edwards prosthetic valve), or when angiographic estimation of the volume of aortic regurgitation is desired. Direct left ventric-
Transthoracic ultrasonic puncture is rarely needed to provide access to that chamber.

Physiologic observations were possible in only some patients after posterior percutaneous left atrial puncture.\(^\text{a}\) In contrast, such unhurried observations may be made virtually routinely in most subjects during transeptal left atrial puncture.\(^\text{b,c,d}\) Studies of true pulmonary blood volume, the effect of anti-gravity suit inflation, drug infusion with isoproterenol (Isuprel) and acetylcholine and venous tourniquet application have been performed in large groups of patients in the course of the studies reported in this paper. Left heart angiography is readily available as a by-product of transeptal atrial puncture. The latter technic is therefore routinely utilized to permit selective left ventricular angiography in subjects with ventricular septal defects. The facility with which the Brockenbrough radiopaque Teflon catheter may be passed from the left atrium to the left ventricle has permitted routine use of this catheter in patients with atrial septal defects. The Teflon catheter is readily passed from the right to the left atrium through the atrial defect especially when the distal curvature is transiently straightened with a transeptal needle kept within the Teflon catheter. After passage into the left atrium, the needle is removed and the catheter tip advanced into the left ventricle as desired.

Varied complications have been reported from diverse laboratories utilizing transeptal left atrial puncture. These include puncture of the free wall of the heart, hemopericardium, systemic arterial embolization, thrombophlebitis, aortic puncture, cardiac arrhythmias, hypotension and chest pain. Mortality has been reported in this and other laboratories.\(^\text{b,c,d}\) It is our firm conviction that most of these problems can be avoided by careful attention to details of the technical approach to transeptal left atrial puncture as described under the section on methods, and by permitting only very limited catheter or needle manipulation in the left atrium in patients with a history of systemic arterial embolization. It must also be recognized that physicians experienced in this technic will have fewer complications than will residents and fellows undergoing training in left heart catheterization procedures. The ease with which this procedure may be performed in the vast majority of patients plus the unequaled opportunity for physiologic measurement thus afforded makes transeptal left heart catheterization the preferred approach to the evaluation of left sided dynamics. The percutaneous approach eliminates the need for saphenous vein cutdown and permits ready repetition of the procedure.

**Summary**

The experience of this laboratory in transeptal left atrial catheterization is described together with details of the technical approach employed. Three hundred ninety successful left atrial punctures have been performed, 65 by the earlier Ross technic, and more recently 325 studies by the percutaneous Brockenbrough approach. Utilizing the latter technic, the left atrium can be entered in 99 per cent of the patients; the left ventricle can be catheterized from the left atrium in 94 per cent of the studies in which attempts are made to manipulate the catheter through the mitral valve. The complications encountered in this and other laboratories are discussed together with means of minimizing and preventing these untoward reactions. The position of transeptal left atrial puncture among the various left heart catheterization procedures is discussed.

**Addendum:** Since this paper was completed an additional 300 transeptal atrial punctures by the Brockenbrough technique have been performed. The left atrium was entered with the Brockenbrough needle and Teflon catheter in 298 subjects. The left ventricle was then catheterized in 295 of these 299 patients.

**Résumé**

L'expérience dans notre laboratoire dans le cathétérisme transeptal de l'oreillette gauche est décrit, en même temps que les détails de la voie d'abord utilisée. On a effectué 390 ponctions de l'oreillette gauche avec succès. 65 par la technique ancienne de Ross, et plus récemment 325
études grâce à la voie percutanée de Brockenbrough. En utilisant cette dernière technique, l'oreillette gauche peut être atteinte dans 99% des malades; le ventricule gauche peut être cathétérisé à partir de l'oreillette gauche dans 94 pour cent des études où l'on essaie de faire passer le cathéter à travers la valvule mitrale. Les complications rencontrées dans notre laboratoire et dans d'autres sont discutées, en même temps que les moyens de réduire et d'éviter des réactions indésirables. Cette étude envisage la place de la ponction transeptale de l'oreillette gauche parmi les divers moyens de cathétérismes du corps gauche.

**ZUSAMMENFASSUNG**

Die Erfahrung dieses Laboratoriums in transeptaler Katheterisierung des linken Vorhofs wird zusammen mit Einzelheiten über das technische Vorgehen beschrieben. 390 erfolgreiche Punktions-


**Complete reference list will appear in reprints.**

For reprints, please write Dr. Samet, Mt. Sinai Hospital, 4300 Alton Road, Miami Beach.

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**VOCAL CORD PARALYSIS FROM CALCIFIED HILAR LYMPH NODE**

A heavy smoker had complete paralysis of the left vocal cord from a large calcified hilar mass. Over three and a half years, he expectorated small pieces of calcified material without the development of infection or fistula, and recovered from the paralysis with marked diminution in the calcification.

Bronchoscopy indicated facelid paralysis of the left vocal cord and normal trachea, carina and both bronchi except some compression of the left-main-stem bronchus. Cytologic studies were within normal limits as were culture and smear for acid-fast bacilli. It was believed that the hoarseness and spitting of stones were related to the large calcified hilar lymph node, presumably owing to inactive tuberculosis.


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**MAGNESIUM METABOLISM**

To determine the significance of magnesium metabolism in the pathogenesis and treatment of hypertension, serum and erythrocytic magnesium calcium sodium and potassium, as well as serum urea nitrogen, creatinine, phosphorus, chloride and carbon dioxide were determined in 20 normal subjects and in 16 hypertensive patients after six and eight weeks of placebo therapy and following 12 weeks of therapy with hydrochlorothiazide. Atomic absorption spectroscopy was used to determine magnesium and calcium.

Hydrochlorothiazide caused a decrease in serum magnesium, but despite this, intracellular magnesium increased significantly. Changes in diastolic blood pressure induced by hydrochlorothiazide correlated with the ratio of the differences of intracellular potassium to intracellular magnesium. These preliminary results suggest that changes in magnesium metabolism influence vascular tone and play an integral role in blood-pressure control.


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**WEGENER'S GRANULOMATOsis**

Wegener's granulomatosis is a generalized disease of unknown etiology characterized pathologically by a polyarteritis similar to periarteritis nodosa, but always involves the respiratory tract—upper, lower, or both, a focal glomerulitis with necrosis and thrombosis of the loops of the capillary tufts of the kidneys, and it may involve the spleen. Involvement of the spleen and lung are uncommon in periarteritis nodosa. This disease should be suspected when there is a destructive lesion of the respiratory tract which progresses in spite of antibiotics and results in death from progressive pneumonitis or renal destruction.

Over one-half of the patients have densities of the lung which may cavitate. Our diagnostic tools of bronchoscopy, bronchial biopsy, and Papanicolaou smear are poor in making the diagnosis of Wegener's granulomatosis. Resection has the same risk as carcinoma of the lung if primary resection is done. Even with resected material, the pathologist did not make the diagnosis the first time in 50 per cent of cases.