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PERCUTANEOUS DIRECT CARDIAC CATHETERIZATION*

A New Method, with Results in 122 Patients

MORRIS J. LEVY, M.D.,† AND C. WALTON LILLEHEI, PH.D., M.D.‡

MINNEAPOLIS, MINNESOTA

COMPREHENSIVE assessment of the aortic valve in severe valvular stenosis, in the presence of peripheral arteriosclerosis and in infants is difficult or impossible by the "retrograde" approach through the aortic valve. In these circumstances various technics for puncture of the left ventricle[1,2] or the left atrium[3-5] have been applied that have offered less opportunity for selective angiography and have resulted in a relatively higher morbidity and mortality. The transseptal technic[6,7] offers an excellent and safe approach for assessment of the mitral valve but is less satisfactory for complete aortic-valve evaluation.

Our approach consists of introducing a small and short catheter directly into the left ventricle (through the chest wall), with subsequent catheterization of the aorta (anterograde approach) and left atrium (retrograde approach).[8] The method has been readily combined with selective angiography at each of the sites entered by the catheter, adding to the completeness of the procedure without increased risk to the patient. The safety of the technic was first tested in animals, and it was subsequently applied in 122 selected patients with predominantly obstructive lesions (both congenital and acquired) of the left side of the heart. In 5 patients complete catheterization (right and left sides of the heart) was also carried out with the use of the same fundamental principle. Indications for this type of catheterization and our results are presented below.

EQUIPMENT AND METHOD

Equipment, consisting of needle, catheter and flushing chamber, was designed.§

An 18-gauge needle, 18 to 22 cm. in length, with a blunt end and diamond-shaped point stylet, was designed for use in adults (needles of 20 and 22 gauge were selected for use in children or infants). Pointed-end Teflon catheters of corresponding sizes (17 to 21 gauge) were made to fit snugly over the needles. A flushing chamber was designed, with attached, movable, metal, spiral, rounded stylet, approximately 30 cm. in length (exceeding the tubing or the needle length by 8 to 13 cm.), a flexible 8-cm. distal part and a metal adapter at the proximal site (Fig. 1).

The safety and applicability of the method was initially tested in animal experiments.

Average-size mongrel dogs were subjected to cardiac-puncture catheterization. The catheter (encasing the needle) was introduced into the left ventricle and advanced into the left atrium or the aorta or both (Fig. 2). There were no evident clinical complications, and in no case was a significant amount of blood found in the pericardial cavity when the animals were killed. After these experiments the method was applied clinically.

With the use of local anesthesia (adults) or general anesthesia (children), the catheter was introduced into the left ventricle (for study of the left side through the intercostal route). With the addition of the spiral, flexible stylet attached to the flushing chamber the catheter was advanced into the ascending aorta or left atrium.

In some cases the right ventricle was entered first (through the substernal approach), and the pulmonary valve assessed. Next, the catheter was advanced through the ventricular septum into the left ventricle, and the procedure completed as described above. From each of the sites entered by the catheter pressure recordings (Fig. 3), blood samples or selective angiography could be readily done.

For aortography the tip of the catheter was usually positioned about 2.5 to 4.0 cm. above the aortic valve. From this level recoil and slipping back into the left ventricle, during the fast injection of dye,

*From the Department of Surgery, University of Minnesota Medical School.

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†Assistant professor of surgery, University of Minnesota Medical School (present address: Beilison Hospital, Tel-Aviv, Israel).

‡Professor of surgery, University of Minnesota Medical School.

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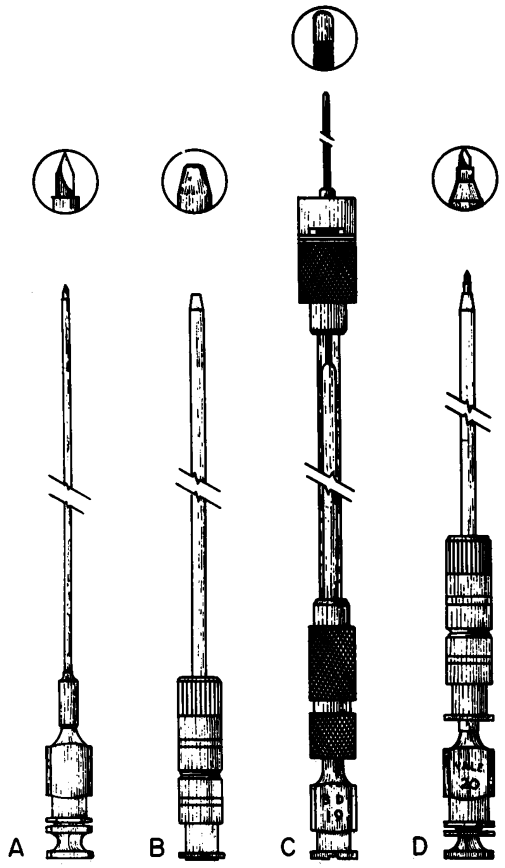

FIGURE 1. *Equipment for Cardiac-Puncture Catheterization. A = needle (with diamond-shaped-point stylet); B = Teflon catheter; C = flushing chamber, with flexible metal guide; and D = needle (in) and catheter (over), snugly fitted one to the other.*

was obviated in the majority of cases. For selective ventriculography the tip of the catheter was placed at the mid-ventricular portion (to prevent recoil and myocardial or pericardial injection). Before each injection of dye (aortography, ventriculography or atriography), the catheter was temporarily sutured to the skin (in the positions mentioned above) to ensure additional stability and to prevent displacement before or during the angiography. An adequate-sized Teflon catheter, with an end hold and two side holes at its distal portion, allowed fast injection (one to one and a half seconds) of the contrast medium, which was 75 per cent diatrizoate (Hypaque).

RESULTS

One hundred and twenty-two* patients were subjected to this procedure. There were 70 males and 52 females ranging in age from eighteen months to sixty-five years (Table 1).

The aortic valve was assessed in 117 cases. Assessment was not attempted in 4. Three of these 4 patients had been admitted to the hospital for evaluation after valve replacement,† and the procedure was interrupted in the fourth by breakage of the stylet. In 1 patient, attempts at assessment were unsuccessful.

The systolic gradient (at rest) across the aortic valve was in a range between 0 and 230 mm. of mercury. In 20 patients heavy calcific aortic stenosis was present, but the valve was crossed by the catheter in each.

The left atrium was entered in 20 patients, and direct pressure recorded in each. Attempts to cross the mitral valve in 3 additional cases were unsuccessful. In 2 of these 3, mitral stenosis was present.

Complete cardiac-puncture catheterization of the right and left sides of the heart was performed in 5 patients. In 1 additional patient this was attempted, but the right ventricle could not be assessed, and only the left side of the heart was evaluated. These were patients with pulmonary stenosis or transposition of the great vessels, conditions in which the standard right-sided catheterization is often incomplete.

Fifty-eight cases were considered to be congenital. In none was a history of rheumatic fever elicited. The majority of patients presented clinical signs of cardiac disease in early infancy, and many showed radiologic features consistent with congenital cardiac malformations (Table 2).

Thirty-nine patients exhibited some form of aortic stenosis (Fig. 4).[9] The majority (23 patients) presented the isolated valvular type of stenosis. The subaortic type was diagnosed in 9 cases. The diffuse form of subaortic obstruction[10] was present in 3 cases, and the discrete form in the remaining 5. The distinction between the two forms was based upon pressure measurements as well as angiography.[11] Supravalvular stenosis was diagnosed in 1 patient, and coarctation in 4.

One other patient, with the clinical impression of defect of the ventricular septum and with catheterization data suggesting a defect of the atrial septum, proved to have a canal between the "left ventricle and right atrium and subaortic stenosis." The patient was operated upon, and the diagnosis confirmed. A common embryologic basis for both anomalies — displacement of the ventricular septum toward the left — was suggested as a possible cause for this extremely rare anomaly.[12]

Of particular interest was a patient manifesting, clinically, a typical congenital aortic insufficiency.

*As of November 1, 1963.

†In subsequent experience in 5 patients with aortic ball-valve prostheses, we have passed the Teflon catheter through the prosthesis and carried out aortography and obtained pullback pressure tracings. No complications of any kind were encountered, and the presence of this small catheter did not appear to affect the ball-valve function significantly.

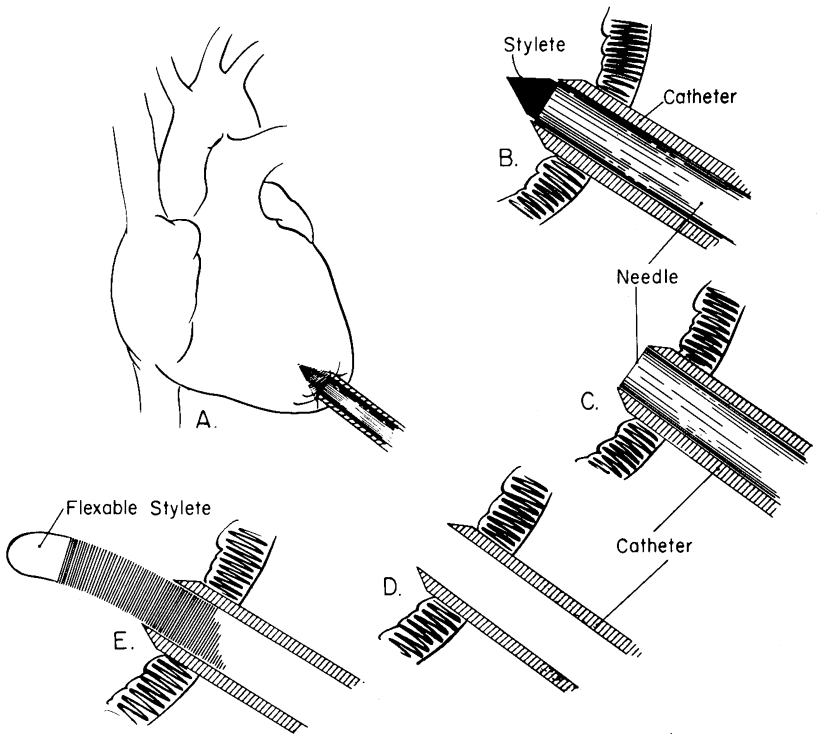

FIGURE 2. *Schematic Representation of the Puncture Technic.*
Through the cardiac apex (A) *the catheter over the needle* (B) *is inserted into the left ventricle (through the chest wall by the intercostal route). The needle is then pulled out* (C), *leaving the catheter* in situ (D). *The flexible guide is next pushed in* (E), *and the catheter advanced over.*

Previous retrograde catheterization was unsuccessful since the catheter could not be made to cross the aortic valve. Selective aortography gave signs of aortic insufficiency. At recatheterization (by the puncture technic) a channel that communicated with the left ventricle and the ascending aorta and bypassed the stenotic aortic valve was demonstrated. Subsequently, 2 additional cases, with identical clinical and radiologic appearance, were diagnosed, and all 3 surgically treated. The "tunnel" (communication between the ascending aorta and the left ventricle) was obliterated through an aortic approach in each, and 2 patients were cured (Fig. 5). This entity, not previously recognized in life, has also been misclassified as a ruptured sinus of Valsalva. The aortic sinuses, in fact, were normal in each of these 3 patients. The aortic ostia of the tunnel began close above the right coronary artery and hence above the right sinus. Identical anatomic findings and the presence of abnormal physical findings simulating aortic insufficiency since infancy, in each of the 3 patients, suggest that this peculiar condition is very probably a congenital malformation.[13]

Sixty-three patients presented acquired lesions, predominantly secondary to rheumatic fever or subacute endocarditis, and 1 was normal. As among the congenital group, aortic stenosis, isolated or combined, was the most common lesion diagnosed in 47 patients (Table 3).

Twenty patients were found to have lesions of the mitral valve. Eight patients had isolated mitral-valve lesions, and in the remaining 12, there was associated disease of the aortic valve.

In 2 of the 4 patients with pure mitral stenosis the diagnosis was based only upon the presence of an "end-diastolic" gradient across the mitral valve at angiography. A filling defect in the left ventricle, suggesting mitral stenosis, was present in 2 cases. Included also in this group are 8 patients who were admitted to the hospital for study after corrective surgery for insufficiency of the mitral or aortic valve (Fig. 6).

One case, in which a heavy calcific valve was evi-

TABLE 1. *Age Distribution at Catheterization.*

AGE yr.	NO. OF PATIENTS
1½-2	3
3-10	29
11-20	19
21 & above	71
Total	122

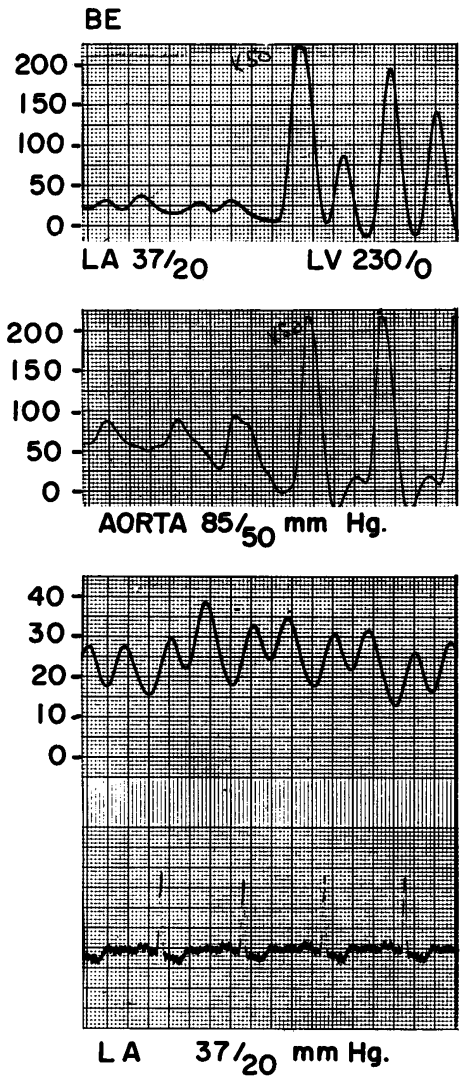

FIGURE 3. *Left-Sided Pressure Tracings (Pullback) from a Patient, Fifty-one Years of Age, Indicating Severe Aortic and Mitral Stenosis (Both Valves Had Been Assessed from the Left Ventricle).*

dent on kymography, is of special interest. Tracing curves indicating aortic and subaortic stenosis were recorded at catheterization. At operation extensive calcification of the aortic valve, also involving the left outflow tract of the ventricle, was present, indicating acquired subaortic stenosis.

COMPLICATIONS

Sixty-eight patients were subjected to operation after the procedure. Hemopericardium (50 to 200 ml.) was found in 6 (8 per cent). One of the patients presented the clinical picture of cardiac tamponade and was treated by pericardiocentesis. Recovery was uneventful.

Mild pleural effusion was evident on x-ray examination of the chest in 2 cases. Neither of the patients required thoracentesis, and the fluid disappeared in a few days.

Three patients exhibited temporary systemic hypotension after the procedure. In 1 other patient, who went into profound shock three days later, bleeding peptic ulcer with massive intestinal hemorrhage was the main finding at autopsy.

On 2 occasions (early in our experience) the flexible metal stylet broke during the procedure and stuck in the left side of the heart. Surgery was performed twenty-four hours later in 1 patient and forty-eight hours later in the other, and both recovered. Elective valvuloplasty was performed in the first case for relief of aortic stenosis, and the foreign body was removed through the aortotomy. (This was the patient mentioned above in whom the aortic pressure was not recorded.) The second patient, an eleven-year-old boy, was admitted to the hospital for postoperative follow-up catheterization. Congenital aortic stenosis had been relieved a year previously. During the procedure, the distal part of the flexible guide broke and

TABLE 2. *Type of Cases for Which Percutaneous Transthoracic Left-Sided Catheterization Was Employed.*

CONGENITAL LESIONS*	NO. OF CASES
Aortic stenosis	32
Valvular	23
Subvalvular	8
Supravalvular	1
Aortic stenosis, with insufficiency	3
Coarctation†	4
Aortic & pulmonic stenosis	1
Tunnel between aorta & left ventricle	2
Aortic stenosis, with mitral insufficiency	1
Canal between left ventricle & right atrium, with subaortic stenosis	1
Miscellaneous abnormalities	14
Total	58

*10 patients studied after operation.
†1 patient with aortic stenosis & 1 with ventricular defect of septum.

TABLE 3. *Acquired Lesions.*

LESION*	NO. OF CASES
Disease of aortic valve	38
Stenosis	18
Insufficiency	8
Stenosis, with insufficiency	12
Disease of mitral valve	8
Stenosis	4
Stenosis, with insufficiency	2
Insufficiency	2
Combined disease of aortic & mitral valves	17
Aortic & mitral stenosis	5
Aortic stenosis, with mitral insufficiency	9
Aortic stenosis, with aortic insufficiency & mitral insufficiency	3
None	1
Total	64

*8 patients studied after operation.

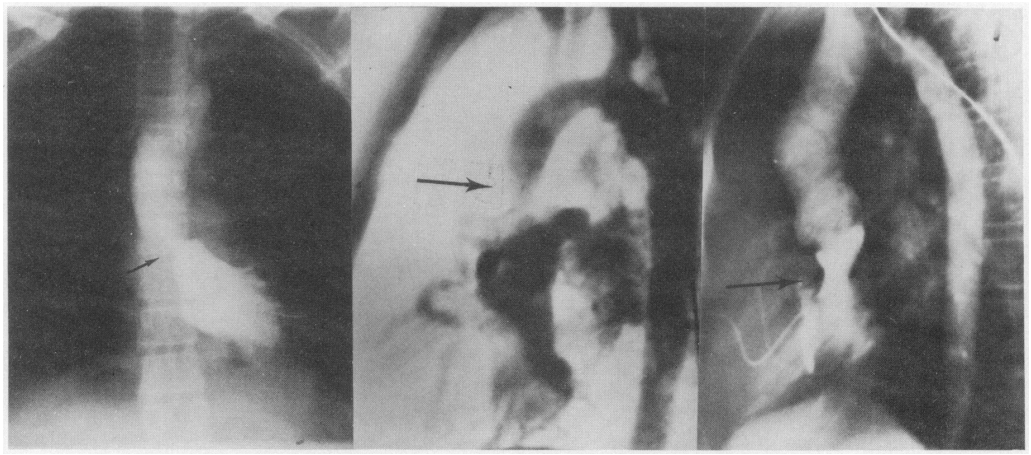

FIGURE 4. *Selective Angiography in Three Forms of Congenital Aortic Stenosis: Valvular (Left), Supravalvular (Center) and Subvalvular (or Diffuse) Type (Right).*

The systolic gradient (at rest) in each patient was above 90 mm. of mercury. In the supravalvular stenosis (center) note the enormously dilated coronary arteries just below the site of obstruction.

stuck at the inflow portion of the left ventricle. It was removed through the left atrium four hours later.

These 2 accidents (fortunately without serious sequelae) were attributed to poor construction of the stylet at the joint between the flexible and nonflexible parts. This junction was later eliminated, and accidents of this nature have since been avoided.

One death was related to the procedure. This occurred in a six-year-old child with a single ventricle and transposition of the great vessels. An attempt at retrograde catheterization was unsuccessful. At puncture massive intramural injection of opaque medium was the cause of cardiac arrest and subsequent death. The catheter, probably not adequately secured to the chest wall, slipped back from the left ventricle and resulted in myocardial injection.

DISCUSSION

Whereas in the vast majority of patients, catheterization of the left side of the heart is successfully performed through the aorta by the retrograde manner (the catheter being advanced in a retrograde direction through the femoral, brachial or subclavian artery),[14-16] in some patients the presence of obstruction along the aorta — coarctation, supravalvular aortic stenosis, peripheral arteriosclerosis or aortic aneurysm — may preclude the retrograde approach.[8] By far the most frequent cause of failure to complete retrograde catheterization has been the presence of aortic stenosis. It has been our experience, as well as that of others,[17] that in approximately 50 to 60 per cent of patients with severe stenosis of the aortic valve, the catheter cannot be threaded across the obstruction (from the aorta) regardless of continuous improvement in technics and equipment.[18,19] Indeed, in some patients with very severe stenosis, it would be distinctly unwise, even if it could be accomplished, since the catheter would seriously compromise the residual orifice present. In these circumstances the catheter is usually kept in the ascending aorta and puncture of the left ventricle performed in addition.* Simultaneous pressures from the aorta through the catheter and from the left ventricle through the needle are then recorded. Opaque medium may be injected through the needle for selective ventriculography, but this has often been associated with a fairly high incidence of myocardial injection, depending upon the experience and dexterity of the examiner and also upon the size of the ventricular cavity. Furthermore, because of the continual movement of the heart and chest wall, a stiff, nonflexible needle may cause damage of an essential structure, such as the chordae tendineae, papillary muscles or even valve tissue. Also, introduction of a stiff needle into the myocardium, under the circumstances, may result in serious pericardial tamponade related to trauma. For that reason, not surprisingly, Björk et al.[20] have recommended a five-minute maximum procedure time for puncture of the left ventricle (to include ventriculography, if it is performed).

In our series angiograms at two sites, at least, were done routinely, with procedure time usually between ten and thirty minutes and, occasionally, up to forty-five minutes, without apparent deteriorating effect upon the patient.

The need, in certain cases, to assess both the aortic and the mitral valve in one procedure is obvious. Trans-septal catheterization[6,7,21] has been clearly demonstrated to have definite advantages for assessment of the mitral valve. However, assessment of the aortic

*At present most patients suspected of having aortic stenosis or other obstructing lesions are catheterized initially by the puncture method herein described rather than via the femoral route.

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