CLINICAL PROGRESS

Retrograde Arterial Catheterization of the Left Heart

Experience with 500 Infants and Children

By Peter Vlad, M.D., Arno Hohn, M.D., and Edward C. Lambert, M.D.

Historically, retrograde catheterization of the arterial circulation appears to have been the first method employed in the study of the left heart. Cournand cites the physiologic studies of Chauveau and Marey. They recorded pressure tracings obtained from the left ventricle of the erect, unanesthetized horse in 1861.

Almost 100 years later, in 1950, three groups of workers reported application of this approach to man. Zimmerman, Scott, and Becker were first to publish. However, they were successful only in patients with aortic regurgitation, being unable to pass through the normal aortic valve. Furthermore, one of their 11 patients succumbed from ventricular fibrillation during the procedure and another died 4 days later. Limón, Rubio, and Bouchard were the first to establish this method as a safe, effective approach in man, allowing passage of the catheter across the normal aortic valve in 17 patients without complications. Later in that year Sodi-Pallares and his group confirmed Limón's success in 25 patients studied in order to obtain the left intraventricular potentials of the human heart.

Unfortunately the morbidity and mortality encountered by Zimmerman's group in man, and those experienced in dogs by Hellem and his associates and by Haddy and co-workers appears to have delayed general acceptance of this method. Only in the past five years has it been recognized as acceptable for diagnostic use for pressure measurements and of special value for selective ventriculography.

More recent is the recognition that it is a useful tool even in the presence of aortic stenosis.

The following is a report of an experience with 542 consecutive catheterizations by the retrograde arterial approach.

Material and Methods

Material

A total of 542 left heart catheterizations were performed in 500 patients by the retrograde arterial method between July 1957 and May 1963. Of these, 499 were accompanied by simultaneous right heart catheterization performed by usual methods. Forty-two patients had two retrograde catheterizations (table 1).

The patients ranged in age from 1 week to 21 years, and 151 of these (30 per cent) were infants (patients under 2 years of age). Table 2 shows the age distribution of the cases. The smallest patient weighed 1.87 Kg. and the largest 80.6 Kg.

Cases were selected for left heart study when (1) significant hemodynamic data were needed from the left heart, (2) the possibility existed of associated anomalies that would be found only by studying the left heart, and (3) it was necessary to exclude an associated ventricular septal
defect, patent ductus arteriosus, mitral regurgitation, or coarctation of the aorta.

These catheterizations were done without regard to age. The seriousness of the abnormality was not used as a contraindication. In all, 32 separate anomalies were studied; 203 cases had more than one hemodynamically significant defect (Table 3).

**Method**

The patients were sedated with an ataractic mixture. Under local anesthesia a peripheral artery (the right or left brachial artery or a superficial femoral artery) was isolated and a transverse incision was made. Bleeding was controlled by rubber bands encircling the artery above and below the arteriotomy. Five to 10 ml. of a dilute heparin-saline mixture were infused into the distal segment of the artery. An ordinary cardiac catheter with a preformed, suitable curve was then inserted into the vessel by a simple metal introducer. The catheter was then directed under fluoroscopic control into the ascending aorta.

Directing the catheter tip through the aortic valve was accomplished by either a straight or looped tip. To pass the catheter as a straight tip into the left ventricle it was positioned with the tip pointing toward the left aortic sinus and rhythmically tapped on the valve. After repeated gentle tapping the catheter usually slipped into the left ventricle (much as originally described by Sodi-Pallares et al.) where it could be positioned as necessary (fig. 1A). This is the maneuver necessary in aortic stenosis. The second approach, that of Limón, Rubio, and Bouchard, consisted of forming a small loop near the end of the catheter and passing it in this doubled form through the aortic valve (fig. 1B). Care was taken in catheter manipulation to avoid coronary artery occlusion. When the approach was from the groin, passage of the catheter around the arch of the aorta had to be gentle in order to avoid vessel trauma.

Entrance into the left atrium was obtained by forming a clockwise half loop of the catheter in the left ventricle with the tip cephalad. Partial withdrawal of the catheter hooked the tip through the mitral valve into the left atrium.

Upon withdrawal of the catheter, free bleeding from the artery both proximal and distal to the arteriotomy was induced. Repair of the vessel was performed by a purse string suture, continuous running suture, or continuous horizontal mattress suture with 6-0 mersilene or silk on anatraumatic

**Table 1**

<table>
<thead>
<tr>
<th>Retrograde Arterial Left Heart Catheterization in 500 Patients</th>
<th>Number</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total attempted retrograde catheterizations</td>
<td>542</td>
<td>100</td>
</tr>
<tr>
<td>Successful entry of left ventricle</td>
<td>499</td>
<td>92</td>
</tr>
<tr>
<td>Angiocardiograms from the left ventricle</td>
<td>337</td>
<td>62</td>
</tr>
<tr>
<td>Simultaneous right heart catheterization</td>
<td>499</td>
<td>92</td>
</tr>
</tbody>
</table>

**Table 2**

<table>
<thead>
<tr>
<th>Five Hundred and Forty-two Retrograde Arterial Left Heart Catheterizations: Age Groups in 500 Patients</th>
<th>Total cases</th>
<th>Success</th>
<th>Per cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age group</td>
<td>0-1 mo.</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>1-6 mo.</td>
<td>70</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>6-12 yr.</td>
<td>166</td>
<td>156</td>
</tr>
<tr>
<td></td>
<td>12-16 yr.</td>
<td>80</td>
<td>77</td>
</tr>
<tr>
<td></td>
<td>Over 16 yr.</td>
<td>28</td>
<td>28</td>
</tr>
<tr>
<td>Total</td>
<td>542</td>
<td>499</td>
<td>92</td>
</tr>
</tbody>
</table>

**Table 3**

<table>
<thead>
<tr>
<th>Retrograde Arterial Left Heart Catheterization: Defects Studied</th>
<th>Double outlet right ventricle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anomalous pulmonary venous return</td>
<td>Ebstein’s malformation</td>
</tr>
<tr>
<td>Aortic regurgitation</td>
<td>Endocardial fibroelastosis</td>
</tr>
<tr>
<td>Aortic septal defect</td>
<td>Hemitruncus arteriosus</td>
</tr>
<tr>
<td>Aortic stenosis</td>
<td>Idiopathic cardiomyopathy</td>
</tr>
<tr>
<td>Atrial septal defect</td>
<td>Marfan’s syndrome</td>
</tr>
<tr>
<td>Chronic constrictive pericarditis</td>
<td>Mitral regurgitation</td>
</tr>
<tr>
<td>Coarctation of the aorta</td>
<td>Patent ductus arteriosus</td>
</tr>
<tr>
<td>Coarctation of the pulmonary artery</td>
<td>Pulmonic regurgitation</td>
</tr>
<tr>
<td>Common A-V canal</td>
<td>Pulmonic stenosis</td>
</tr>
<tr>
<td>Complete transposition of the great vessels</td>
<td>Ruptured sinus of Valsalva</td>
</tr>
<tr>
<td>Congenital A-V block</td>
<td>Single ventricle</td>
</tr>
<tr>
<td>Coronary arterio-venous fistula</td>
<td>Tetralogy of Fallot</td>
</tr>
<tr>
<td>Corrected transposition of the great vessels</td>
<td>Tricuspid atresia</td>
</tr>
<tr>
<td>Dextrocardia</td>
<td>Truncus arteriosus</td>
</tr>
<tr>
<td>Vascular ring</td>
<td>Ventricular septal defect</td>
</tr>
</tbody>
</table>
needle. Early in the series and with small arteries the vessels were ligated with 3-0 silk.

During the entire procedure right and left heart pressures and electrocardiograms were continuously monitored on an oscilloscope.

Results

In 542 arterial catheterizations failure to enter the left ventricle occurred 43 times, an over-all success rate of 92 per cent (table 1). Fifteen per cent of 203 attempts in which the cutdown was performed in the groin were unsuccessful, while 4 per cent of 339 attempts from the antecubital fossa failed (table 4).

Of the 115 catheterizations in patients with aortic stenosis, it was impossible to enter the left ventricle 13 times (table 5). Thus, for aortic stenosis (of all types), a success rate of 89 per cent was obtained. Seven of eight cases failed in which the approach was from the groin.

In the absence of aortic stenosis 18 of the 30 failures were in patients under 2 years of age, a failure rate of 12 per cent. In 14 of the

30 failures it was not possible to enter the ascending aorta.

The left atrium was entered from the left ventricle 51 times in approximately 90 instances when a deliberate attempt was made to enter this chamber with a curved-tip catheter.

Morbidity and Mortality

Two deaths occurred. In addition, there were four cases of ventricular fibrillation. One patient developed a transient hemiparesis and in two patients a laceration was produced in the ductus arteriosus. In a single instance postcatheterization peripheral vascular insufficiency was observed. In 49 patients who died from causes unrelated to catheterization no evidence of injury to the heart valves or endocardium was seen at postmortem examination.

Discussion

Analysis of the data presented confirms the value of retrograde arterial left heart catheterization, particularly in a pediatric age group. The over-all success rate presented (92 per cent) compares favorably with any published reports employing any technic in infants and children. Brockenbrough et al. noted an 88-per cent success rate in 51 children with the anterior percutaneous puncture of the left ventricle, and Roveti, Ross and Bahnson had an 85-per cent success rate with the transseptal route in 20 pediatric patients. This high rate of success with retrograde methods has also been reported by Green, Ziegler, and Kavanagh-Gray. They were successful in entering the left ventricle in 88 of 100 patients.

Retrograde arterial left heart catheterization as described has certain advantages. Access to a peripheral artery through an already estab-
lished cutdown (for venous catheterization) without the use of additional anesthesia makes the procedure convenient. All measurements may be made on unanesthetized patients. In the method outlined no special catheters, guides, or other equipment is necessary. Closed-tip catheters can be used. These offer distinct advantages in that during selective angiocardiology they diminish the incidence of catheter recoil with powered injections and minimize the hazard of myocardial infiltration and perforation. In contrast, catheters introduced by percutaneous methods must be open tipped. In addition, percutaneous methods of retrograde arterial left heart catheterization do not lend themselves readily to infants because of the small size of the arteries involved.

Another virtue of retrograde arterial catheterization is that valuable information can be gathered from the central aortic system. Pressure determinations and selective angiography can exclude or detect coartation of the aorta, vascular rings, patent ductus arteriosus, supravalvular chambers, coronary anomalies, and aortic regurgitation. In addition, it constitutes an excellent method for localizing the site of aortic stenosis.

The results described indicate that the failure rate varied with the cutdown site (table 4). The vessels of the antecubital fossa offered a higher rate of success (96 per cent) than did those of the groin (85 per cent). Either arm was used with excellent chance of success. Only five instances of failure to pass the catheter into the ascending aorta from the arm were recorded. Access to the left heart was gained in 291 of 301 attempts from the right arm, and 35 of 37 from the left arm. The latter procedure was more difficult, however, as originally pointed out by Sodi-Pallares et al.\(^6\) This is due to the arrangement of the vessels arising from the arch of the aorta. Frequently in such instances the catheter passed into the descending aorta instead of into the arch. A similar situation existed when the right arm was used and there was an anomalous origin of the right subclavian artery distal to the left. This occurred in two patients in this series.

In infants and small children, when the approach was from the groin, the technic offered 11 per cent less chance of success than when the procedure was used in older patients. In 151 tests (in 146 infants) data from the left ventricle were obtained in 127, for a success rate of 84 per cent. Closer analysis of the 151 tests disclosed the following reasons for failure in the 24 cases: aortic stenosis (six), the inability to round the arch of the aorta (eight—four cases of coarctation of the aorta, two inappropriate catheter curves, two cases where the patent ductus arteriosus could not be avoided), and 10 unexplained. When there was no aortic stenosis, and the catheter could be passed around the arch of the aorta to the valve, we were able to enter the left ventricle in 126 of 137 cases (92 per cent).

Reference has been made to the fact that aortic stenosis presents special problems. The over-all success rate was 89 per cent. Retrograde arterial catheterization was unsuccessful in all but one of seven infants. These seven and one 5-year-old boy were the only patients with this anomaly in whom the heart was approached from the groin, and all but one failed.

In the other cases of aortic stenosis when the valve was approached from the arm a success rate of 94 per cent was obtained. This is essentially the same as that obtained in cases with unobstructed valves. The severity of stenosis had no bearing on the rate of failure. Four of the six failures with a brachial approach occurred in two patients.

Similarly, the site of stenosis had little bearing on the success rate. Of the 13 failures, one had subvalvular stenosis and one had combined supravalvular and subvalvular obstructions.

It is obvious that the presence of a catheter in a stenotic orifice may exaggerate the degree of obstruction. Only two cases of aortic stenosis were studied by both retrograde methods and anterior percutaneous puncture of the left ventricle. These two cases had peak systolic gradients across the stenosis of 68 and 78 mm. Hg, respectively. The gradients were unaffected by the presence of the catheter.

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Passing a catheter across the aortic orifice may be time consuming. For this reason it is essential to use radiation-saving devices (image intensification and pulsing fluoroscopy).

The difficulties encountered during retrograde arterial catheterization of babies with aortic stenosis also occurred in babies with coarctation of the aorta. A catheter could not be passed across the coarctation in four of 15 infants with this obstruction. In another three the aortic valve was not crossed, bringing the left heart catheterization failures to seven. Diagnostic aortograms were obtained in all cases, however.

Left atrial catheterization with the retrograde arterial method was first reported in dogs by Hellemm et al.,7 and in occasional instances in man by Bierman18 and by Fisher.19 Despite the fact that catheterization of the left atrium was not consistently sought, it was possible to enter this chamber from the left ventricle 51 times. (None of the patients had mitral stenosis.) Use of a straight-tip catheter, such as in cases of aortic stenosis, precludes any trial for left atrial entry. However, the 51 successes indicate that left atrial catheterization by the retrograde arterial approach may be accomplished in a significant number of cases.

The complications encountered (table 6) have been experienced by others,20,21 and were no more frequent than those recorded by other methods.22 Of the two deaths, one occurred 5 days following catheterization in an 11-month-old baby with complex anomalies including a single ventricle, transposition of the great vessels, and severe coarctation of the aorta. On postmortem examination death appeared to be due to renal artery thrombosis, which may have been related to the arterial catheterization. The only other death occurred in a 6-week-old baby with a single ventricle and associated cardiac anomalies as a result of perforation of the left ventricle related to left ventriculography.

Of the few arrhythmias observed, ventricular fibrillation was the most frequent (four cases). This occurred in conjunction with selective angiocardiography and was less frequent than with the right heart catheterizations performed during the same time period. Two cases of fibrillation followed injection of the contrast media. The other two preceded injection and were due to faulty ground connection of an automatic power syringe and were, therefore, avoidable. All four were promptly and successfully treated by external defibrillation without complication.

The incidence of premature beats resulting from manipulation of the catheter in the left ventricle appeared less frequently than during right heart catheterization. Serious arrhythmias such as significant ventricular tachycardia, atrial flutter or fibrillation, supraventricular tachycardia and complete heart block did not occur in this series.

The single case of a cerebral vascular accident took the form of a transient hemiparesis occurring 3 hours following catheterization in a 4-year-old acyanotic girl. Two previous catheterizations and open-heart surgery had been performed elsewhere. Complete recovery followed, but later the child died after a second open-heart operation. At postmortem examination no evidence of subacute bacterial endocarditis, mural thrombosis, or trauma to the valves was noted. A similar lack of valve pathology has already been referred to previously in the 48 other autopsied cases.

An occluded ductus and a patent ductus arteriosus were lacerated in two infants with complex anomalies while the catheter was being manipulated around the arch of the aorta. Prompt thoracentesis successfully treated the resulting hemothorax. This empha-

Table 6

<table>
<thead>
<tr>
<th>Hazard</th>
<th>Number</th>
<th>Per cent</th>
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<tbody>
<tr>
<td>Mortality</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Morbidity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ventricular fibrillation</td>
<td>4</td>
<td>0.7</td>
</tr>
<tr>
<td>Other serious arrhythmias</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cerebral vascular accident</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Trauma to ductus arteriosus</td>
<td>2</td>
<td>0.4</td>
</tr>
<tr>
<td>Peripheral vascular insufficiency</td>
<td>1</td>
<td>0.2</td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>1.5</td>
</tr>
</tbody>
</table>
sizes the need to be gentle in maneuvering the catheter tip around the aortic arch in infants.

Arteriotomy repair with loss or diminution of peripheral pulsations has been noted in about one third of the patients. In spite of absent peripheral pulses, only one case of peripheral vascular insufficiency was noted. This problem occurred in a 12-year-old boy who underwent a combined right and left heart catheterization to evaluate a ventricular septal defect complicated by aortic regurgitation. Four hours following the catheterization the forearm and hand were noted to be cold, cyanotic, and pulseless. Both arterial and venous thrombosis occurred. Treatment consisted of stellate ganglion block, heparin, and thrombolytic agents. Color and temperature returned to normal within 6 days. While the radial pulse remains absent, function is returning.* It is not certain whether this problem is related to the arteriotomy repair or to venous obstruction. The need for meticulous arteriotomy repair is to be emphasized. If free bleeding from the distal arterial segment is not obtained, it must be cannulated with large bore polyethylene tubing. Suction may then be applied and clots from previous stasis removed. Free flow from this segment should then ensue.

Early in our series all small arteries were ligated. No disparity of limb growth has been noted. Many patients have been followed 3 to 5 years.

Voci and Hamer 23 reported that about one third of 80 patients studied had absent peripheral pulses following arteriotomy repair. Vengsarkar and Swan 24 noted transient reduction or absent peripheral pulses in 31 per cent of 125 arteriotomies. Most of these returned to normal within 3 days and there was no tissue morbidity.

The two deaths and eight complications observed give a mortality rate of 0.4 per cent and a morbidity rate of 1.5 per cent. This is a relatively low risk considering that many of the patients were critically ill, and 10 per cent of these patients went on to die of their disease at a later date.

Summary and Conclusions

Five hundred forty-two retrograde arterial left heart catheterizations were performed in 500 infants and children with a successful entry into the left heart in 92 per cent of all attempts. When the brachial artery could be used, the success rate was even higher (96 per cent).

A unique advantage of the retrograde approach was that it permitted a detailed study of the left ventricular outflow tract and central aorta. This information was obtained in 89 per cent of 115 cases of aortic stenosis.

Two critically ill infants died as a result of the test, and there were eight other complications.

As a result of the above findings we believe retrograde arterial catheterization of the heart to be a relatively safe, practical, and effective method for studying the left heart of infants and children.

References

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