Percutaneous Heart Catheterization
in Infants and Children

II. Prospective Study of Results and Complications in
127 Consecutive Cases

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SUMMARY
In this prospective study of 150 consecutive heart catheterizations, the percutaneous method of right and left heart catheterization was used in 127 patients. In infants and children weighing more than 10 pounds, the percutaneous method was found to be an effective technic associated with a 3% incidence of diminished arterial pulses in the catheterized limb. All patients in this weight group, except one, had left heart catheterization by this technic. The method was deemed time-saving compared to a cutdown, and complications related to the use of end-hole catheters and guide wires were minimal.

With regard to venous catheterization, a previous femoral vein cutdown contraindicated application of the percutaneous method to the same vein, while a previous saphenous vein cutdown did not interfere. A vessel catheterized percutaneously may be recatheterized without difficulty.

Thrombi in the arterial catheter and small size of the patient were two factors which had significant correlation with the delay in return of distal pulses to normal. Palpation of distal pulses before and at intervals following the catheterization was found to be the most satisfactory way of detecting arterial complications.

Additional Indexing Words:
Retrograde left heart catheterization
End-and-side-hole catheters

THE technic for percutaneous insertion of catheters into arteries and veins was described by Seldinger in 1953.1 Lurie and associates2 reported modifications of the method which made it more suitable for use in infants and children. Use of the percutaneous technic of catheter insertion in only four children 2 years of age or younger in the American Heart Association's "Cooperative Study on Cardiac Catheterization"3 indicates that the method has not been widely accepted.

Two of the authors (P. R. L. and E. L. P.) have used the percutaneous method of cardiac catheterization routinely since 1962 and have found it applicable to newborns as well as to older children. The method has been used routinely in children weighing 10 pounds or more. The purpose of this report is to present the findings of a prospective analysis of 150 consecutive cardiac catheterization studies, in 127 of which the percutaneous method was used successfully. Material and technics are described in a companion paper.4

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Methods

Patient Material

One hundred and forty-eight patients underwent 150 consecutive cardiac catheterization studies at Childrens Hospital of Los Angeles between September 1, 1968, and April 8, 1969. The ages ranged from 1 day to more than 16 years (fig. 1).

With one exception, a child weighing 11 pounds, the percutaneous technic for insertion of catheters into both a femoral artery and femoral vein was attempted in all children weighing 10 pounds or more. No consistent effort was made to catheterize percutaneously the infants who weighed less than 10 pounds. Blood samples for oximeter readings and central vascular pressure recordings were obtained routinely. Most studies included selective cineangiocardiography, and an average of four injections of contrast material at pressures of 300 to 600 psi (pounds/inch²) were made per study. Many studies included recording of indicator curves after injection of indocyanine green or after inhalation of hydrogen. The cardiac diagnoses are listed in table 1.

Operators

Five full-time pediatric cardiologists and two trainees participated in the study. Their experience ranged from that of a novice attempting his first catheterization to that of an individual who had performed several hundred percutaneous studies. The trainees as well as the staff members having less experience frequently required assistance both with insertion of catheters and with subsequent manipulation in the heart or great vessels by a more experienced operator. The number of studies performed by individual operators ranged from two by a staff physician to 36 by a trainee.

Collection of Data

Using a procedure check list for each of the 150 catheterization studies, the following data were recorded prospectively:
1. Patient information: age, weight, cardiac diagnosis, hemoglobin and hematocrit, technic and site of prior catheterization studies
2. Catheter placement: method of catheter insertion (percutaneous or cutdown), number of

![Figure 1](image)

**Figure 1**

Age distribution of patients undergoing 150 catheterization studies by cutdown, percutaneous, or both technics. Three patients (ages 5 mo, 28 mo, and 7 yr) are shown as having both percutaneous (arterial) and cutdown (venous) methods of catheter insertion. Mean and median age is for group studied percutaneously.
catheters employed, site of attempted and actual insertion, time required to insert catheters (measured from time of lidocaine infiltration), number of times each vessel was punctured before successful insertion of catheter, occurrence of arteriospasm (loss of diminution of femoral pulse) before successful insertion of catheter, degree of hematoma at catheterization site (graded 0 to 2+), extravascular passage of guide wire; presence or absence of clots in catheter lumen (determined by vigorously flushing catheter contents into a gauze pad immediately after removal of the catheters from patient), duration of procedure.

3. Course of diagnostic study: cardiac chambers and great vessels entered and route utilized for entry; number of angiographic studies

4. Assessment of arterial recovery

a. Comparison of skin temperatures of the feet of the catheterized and uncatheterized legs before the study, 30 min after catheter removal, 4 to 12 hours later, and again 18 to 24 hours after conclusion of the procedure. In 27 patients a thermistor probe was used to assess the accuracy of tactile appraisal of skin warmth. Before catheterization none of the 27 patients evaluated with the probe had differences in skin temperatures greater than 0.2 C between the two feet. The examiners were consistently able to detect by palpation any differences in skin temperature exceeding 0.5 C.

b. Comparison of intensity of arterial pulses in the right and left femoral, posterior tibial, and dorsalis pedis arteries was made before catheterization, 30 min after removal of catheter, 4 to 12 hours later, and again 18 to 24 hours after conclusion of the procedure.

c. Patients who did not have equal pulses and equal skin temperatures in both legs within 24 hours after the catheterization study were reexamined 2 weeks later at which time simultaneous flush blood pressures and skin temperatures were determined and pulses were evaluated. Patients with persistently abnormal findings were reappraised at approximately monthly intervals during the first 6 mo following the catheterization.

5. Major complications were recorded in an effort to evaluate incidence of their occurrence and for relationship to percutaneous methodology.

6. Minor complications (arrhythmias, febrile reactions, catheter recoil or intramyocardial extravasation during injection of contrast material, damage to guide wires and catheters, and post-catheterization bleeding) were recorded for evaluation.

### Results

**Success Rate of Percutaneous Entry**

Percutaneous insertion of catheters was attempted in 130 of the 150 consecutive studies. Catheterization of a femoral artery, attempted in 128 cases, was accomplished in 125. No failure was encountered in 122 children weighing 10 pounds or more; however, percutaneous arterial catheterization was successful in only three of six attempts in those weighing less than 10 pounds. Percutaneous catheterization of a femoral vein, attempted in 123 cases, was successful in 119. Two failures occurred in children weighing more than 10 pounds, both of whom had previously had bilateral femoral vein cutdowns (fig. 2). Previous saphenous vein cutdowns in 17 patients did not interfere with percutaneous entry into the femoral vein. Only three of five attempts to catheterize the

### Table 1

<table>
<thead>
<tr>
<th>Heart Defects Observed in 150 Consecutive Catheterization Studies</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic valve stenosis</td>
<td>9</td>
</tr>
<tr>
<td>Atrial septal defects</td>
<td></td>
</tr>
<tr>
<td>Primum</td>
<td>1</td>
</tr>
<tr>
<td>Secundum</td>
<td>8</td>
</tr>
<tr>
<td>Atrioventricular canal defect</td>
<td>3</td>
</tr>
<tr>
<td>Coarctation of aorta</td>
<td>8</td>
</tr>
<tr>
<td>Constrictive pericarditis</td>
<td>1</td>
</tr>
<tr>
<td>Cor triatriatum</td>
<td>1</td>
</tr>
<tr>
<td>Ebstein's anomaly</td>
<td>1</td>
</tr>
<tr>
<td>Endocardial fibroelastosis</td>
<td>2</td>
</tr>
<tr>
<td>Familial primary pulmonary hypertension</td>
<td>1</td>
</tr>
<tr>
<td>Infrahepatic interruption of inferior vena cava</td>
<td>1</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>2</td>
</tr>
<tr>
<td>Normal heart</td>
<td>3</td>
</tr>
<tr>
<td>Patent ductus arteriosus</td>
<td>9</td>
</tr>
<tr>
<td>Pericardial defect</td>
<td>1</td>
</tr>
<tr>
<td>Peripheral pulmonary artery stenosis</td>
<td>3</td>
</tr>
<tr>
<td>Pulmonary valvar stenosis</td>
<td>17</td>
</tr>
<tr>
<td>Single ventricle</td>
<td>4</td>
</tr>
<tr>
<td>Supravalvar aortic stenosis</td>
<td>3</td>
</tr>
<tr>
<td>Tetralogy of Fallot</td>
<td>17</td>
</tr>
<tr>
<td>Transposition complexes</td>
<td></td>
</tr>
<tr>
<td>D-transposition</td>
<td>6</td>
</tr>
<tr>
<td>L-transposition</td>
<td>5</td>
</tr>
<tr>
<td>Double outlet right ventricle</td>
<td>3</td>
</tr>
<tr>
<td>Tricuspid atresia</td>
<td>1</td>
</tr>
<tr>
<td>Truncus arteriosus</td>
<td>3</td>
</tr>
<tr>
<td>Ventricular septal aneurysm</td>
<td>2</td>
</tr>
<tr>
<td>Ventricular septal defect</td>
<td>33</td>
</tr>
<tr>
<td>Ventricular septal defect with aortic insufficiency</td>
<td>2</td>
</tr>
</tbody>
</table>
femoral vein percutaneously were successful in infants weighing less than 10 pounds. In 11 patients, two catheters were inserted into the right femoral artery and, in two patients, two catheters were inserted into the right femoral vein; all dual catheter insertions attempted were successful.

**Time Required to Insert Catheters**

The time required to insert both arterial and venous catheters, measured from the time of lidocaine infiltration, averaged 21 min per patient. It took an average of 11 min to catheterize the first vessel, and an additional 10 min to catheterize the second. The average time required to insert the arterial and venous catheters varied considerably among the several operators, the longest average being 32 min and the shortest 11 min. These average times include that for insertion of a third catheter in 13 cases which was usually done by a more skilled operator.

**Repeat Percutaneous Catheterization**

Two of the patients in the series who underwent percutaneous venous and arterial catheterizations were restudied during the 7-mo period. At the time of the second study, catheters again were inserted percutaneously into the same vessels used initially.

**Success in Entering Cardiac Chambers and Great Vessels**

In each of the 125 patients in whom the femoral artery was catheterized percutaneously, the catheter was manipulated retrograde across the aortic valve. Among those studied were nine with valvar aortic stenosis, three with supravalvar aortic stenosis, and eight with coarctation of the aorta. In each of three patients with origin of both great vessels from...
the right ventricle, the retrograde arterial catheter was manipulated across a ventricular septal defect into the left ventricle.

The venous catheter entered the right ventricle in 118 of the 119 percutaneous right heart studies, the one failure occurring in a child with tricuspid atresia. The pulmonary artery was entered in all children in whom the pulmonary outflow tract was normal as well as in those with pulmonic valvar stenosis. The pulmonary artery was catheterized in 13 of the 17 cases of tetralogy of Fallot and in eight of the 14 children with transposition complexes. In transposition of the great arteries with ventricular septal defect, the retrograde arterial catheter was advanced into the pulmonary artery after traversing the ventricular septal defect.

Arterial Recovery after Percutaneous Catheterization

Time Profile of Arterial Recovery

Femoral, dorsalis pedis, and posterior tibial pulses returned to normal in all but four of the 122 children weighing more than 10 pounds who underwent percutaneous femoral artery catheterization (table 2). Recovery of pulses was observed within 30 min after catheter removal in 75 (61%), within 12 hours in 103 (84%) and within 24 hours in 114 (93%). Four additional patients recovered normal arterial pulses after discharge from the hospital, three within 2 weeks and the fourth by 4 months. Thus 118 (97%) of the 122 children had normal arterial pulses in the catheterized extremity within 6 months of the procedure. In the remaining four cases, the arterial pulses, though palpable, were quite diminished. In these four children, the flush blood pressure in the catheterized leg remained 25 to 35 mm Hg lower than in the other leg.

During the first 4 hours following catheterization, skin temperatures of the two legs did not correlate with presence of arterial pulses. However, normal skin temperature often preceded recovery of arterial pulses from 4 to 24 hours after the procedure. Furthermore, the presence of normal skin temperatures at 24 hours in children with still absent pulses without exception was predictive that pulse recovery would ensue. Skin temperature became normal even in the children with persistently diminished pulses.

In the three infants weighing less than 10 pounds in whom percutaneous arterial catheterization was performed, the femoral and posterior tibial pulses returned to normal within 12 hours; however in two of these babies the dorsalis pedis pulse, which had been normal before catheterization, remained absent. In each of the three, simultaneous flush blood pressure measurements and skin temperature measurements were equal in the two legs within 12 hours after removal of the arterial catheter.

Factors Related to Delayed Arterial Recovery

Only low patient weight and the presence of thrombi within the arterial catheter when examined immediately after removal from the artery could be correlated with delayed postcatheterization arterial recovery. The time required for recovery of arterial pulses is correlated with weight of the patient in table 3. In table 4, the presence of thrombi in the arterial catheter is correlated with the time of pulse recovery in 121 of the 122 patients weighing more than 10 pounds. Luminal thrombi in the arterial catheter were found in the majority of instances in which pulse

Table 2

<table>
<thead>
<tr>
<th>Pulse recovery time</th>
<th>Within 30 min</th>
<th>Within 12 hr</th>
<th>Within 24 hr</th>
<th>Within 2 wk</th>
<th>Over 2 wk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumulative total</td>
<td></td>
<td>--------------</td>
<td>--------------</td>
<td>-------------</td>
<td>-----------</td>
</tr>
<tr>
<td>No. of patients</td>
<td>75</td>
<td>103</td>
<td>114</td>
<td>117</td>
<td>118</td>
</tr>
<tr>
<td>%</td>
<td>61</td>
<td>84</td>
<td>93</td>
<td>96</td>
<td>97</td>
</tr>
</tbody>
</table>
remained diminished pulses

Arterial Catheter dorsalis

Absent 85 17 9
Present

Time:

Summary of procedure, persistently abnormal recovery was (1) with recovery shown between insertion, evidence of Thrombi lumen 12

mean (lb) 

interval of the mean (lb) 

*This figure includes four patients in whom leg pulses remained diminished and two in whom only dorsalis pedis pulse was lost.

Table 4
Correlation Between Presence of Thrombi in Arterial Catheter and Pulse Recovery Time in 121 Patients Weighing More Than 10 Pounds*

<table>
<thead>
<tr>
<th>Thrombi in catheter lumen</th>
<th>Pulse recovery time</th>
<th>Within 12 hr</th>
<th>12 to 24 hr</th>
<th>Over 24 hr</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td></td>
<td>17</td>
<td>9</td>
<td>5</td>
<td>31</td>
</tr>
<tr>
<td>Absent</td>
<td></td>
<td>85</td>
<td>5</td>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>102</td>
<td>14</td>
<td>5</td>
<td>121</td>
</tr>
</tbody>
</table>

*χ² = 29.783; P < 0.005.

recovery was later than 12 hours and in all in which recovery was delayed beyond 2 weeks as well as in those instances in which persistently abnormal pulses were found.

Delay in pulse recovery beyond 12 hours showed no statistically significant correlation with (1) duration of the catheterization procedure, (2) hemoglobin concentration, (3) evidence of arteriospasm during catheter insertion, or (4) additional needle punctures of the artery after unsuccessful efforts to insert the guide wire (table 5). Four patients in whom significant hematomas developed at the catheterization site had normal pulses within 12 hours.

Major Complications

Major complications occurred in seven of the 150 catheterization studies (4.7%), an incidence comparable to that of 4% reported in the "Cooperative Study on Cardiac Catheterization." Two of the complications may be related to use of percutaneous methodology. Inferior vena caval thrombosis, presumably secondary to femoral vein thrombosis at the site of catheter entry, occurred in a 2-year-old child studied while in severe right heart failure. Hemopericardium due to perforation of the right ventricular outflow tract with a guide wire occurred in a 2-year-old child with tetralogy of Fallot.

The five major complications not related to the use of percutaneous methods included two deaths,* one brief episode of ventricular output

Table 5
Influences of Hemoglobin Level, Number of Arterial Punctures, Arteriospasm, and Duration of Catheterization Upon Pulse Recovery Time

<table>
<thead>
<tr>
<th>Factors*</th>
<th>No. of cases</th>
<th>Pulse recovery time</th>
<th>Within 12 hr</th>
<th>Over 12 hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>125</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemoglobin &gt; 15 g/100 ml</td>
<td>28</td>
<td>22/28 (79%)</td>
<td>6/28 (21%)</td>
<td></td>
</tr>
<tr>
<td>Two or more punctures of catheterized artery</td>
<td>26</td>
<td>19/26 (73%)</td>
<td>7/26 (27%)</td>
<td></td>
</tr>
<tr>
<td>Arteriospasm during procedure</td>
<td>14</td>
<td>11/14 (79%)</td>
<td>3/14 (21%)</td>
<td></td>
</tr>
<tr>
<td>Mean duration of procedure</td>
<td>86 min</td>
<td>85 min</td>
<td>91 min</td>
<td></td>
</tr>
</tbody>
</table>

*None of these factors are significantly correlated with the pulse recovery time by chi-square test at P value of 0.1 or less.

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fibrillation responding promptly to counter-shock, one grand mal seizure following inadvertent injection of contrast material into a carotid artery, and one instance of transient, unexplained seizure activity occurring 12 hours after an uneventful catheterization study.

Minor Complications

Minor complications definitely related to percutaneous methods occurred in five patients. Four, previously discussed, had persistently diminished blood pressures and arterial pulses in the catheterized extremity. These four had no symptoms or other signs of impaired circulation to the limb. An additional arterial complication occurred in one patient in whom a guide wire was wedged into the lumen of a small branch of the left external carotid artery. On retraction of the wire, a segment of endothelium was stripped out. Transient bradycardia and hypotension ensued, but no other sequela were detected.

Recoil of a catheter during injection of contrast material with the pressures of 300 to 600 psi used in our laboratory is a problem not unique to percutaneous end-hole-with-side-holes catheters but may occur more frequently than with closed-end angiographic catheters. In this study, catheter recoil occurred during 24 of the 507 (4.7%) injections of contrast material made through the percutaneous catheters. Minimal endomyocardial staining occurred with nine of the 507 injections (1.8%), but there were no instances of deep myocardial infiltration of the injectate.

Discussion

Percutaneous methods for cardiac catheterization studies of infants and children have not been widely accepted by pediatric cardiologists. Many feel that the methods are not feasible for application to the small child or suggest that the hazards are greater than with the traditional cutdown methods for insertion of catheters. Some have tried the percutaneous method without success, and some have experienced a high incidence of complications. In the present study there was no failure of an effort to catheterize an artery or vein, or both, in children weighing more than 10 pounds, except in two with previous bilateral femoral vein cutdowns. Furthermore, the use of guide wires to assist in manipulation of the percutaneous catheters provided a high success rate in entering sites within the circulation. One of the authors (E.L.P.) in a study of 110 patients with valvar aortic stenosis catheterized the left ventricle retrograde in 105 (unpublished data). This success rate compares favorably with that reported by others\(^5\) not using guide wires to assist manipulation.

Catheter manipulation represents one of the chief causes of hazard during cardiac catheterization. The use of multiple catheters can reduce significantly the amount of manipulation by permitting bits of data to be gathered simultaneously rather than sequentially and by obviating the need to withdraw a catheter from a site attained with difficulty to carry out other parts of the study. The insertion of two catheters into the same femoral vein or artery, or both, has not resulted in a higher incidence of vessel obstruction after catheterization.

A high incidence of vessel obstruction after percutaneous catheterization has been a criticism leveled at the method.\(^5\) In our experience the incidence of obstruction is low. The single instance of femoral vein thrombosis reported in this series is the only case of venous obstruction in our total experience with percutaneous studies. Vlad and associates\(^6\) reported that approximately a third of their 500 patients had diminished pulses following arterial cutdown. Subsequently Hohn and co-workers\(^7\) reported finding clinically abnormal arterial pulses in only 4% of 75 cases after percutaneous catheterization, but recommended that 10 kg (22 lb) be selected as the lower weight limit. In the present series, only 3% of 122 patients weighing 10 pounds or more had clinically abnormal arterial pulses. Since completion of this study, one of us (E.L.P.) using slight modifications of the technic*, has performed percutaneous arterial catheterization in nine infants (weights, 5.5 to 10

\(^*\)Catheters used in this group of infants were made from 20 G nonradioopaque Teflon tubing. The tips had no side holes and were tapered to fit an 0.025-inch wire guide.
pounds), each having recovery of femoral, dorsalis pedis, and posterior tibial pulses within 30 min after removal of the catheter. We feel, therefore, that weight limits are arbitrary and that the 3% incidence of persistently diminished pulses found in the present study is not an irreducible minimum.

In a study of arterial complications following brachial arteriotomy, Jeresaty and Liss noted diminished radial pulses in patients whose blood pressures were equal in both arms. We suggest that our similar observations in the present series may be explained on the basis of embolic occlusion of small arteries distal to the puncture site. The high correlation of delayed arterial recovery with the presence of clots in the arterial catheter at the termination of the procedure in this series suggests that such clots may be a major cause of postcatheterization arterial obstruction. Such clots may be wiped off the catheter tip or from the side holes as the catheter is withdrawn through the vessel wall.

Efforts to minimize the incidence of arterial obstruction should include (1) proper preparation of needles, dilators, and catheter tips, (2) prevention of arteriospasm by adequate infiltration of lidocaine and by use of catheters with high surface lubricity such as those made of Teflon, and (3) careful flushing of catheters to minimize clotting.

Other complications, not seen in this series, have occurred infrequently in our larger experience. Post-catheterization hemorrhage has occurred in four or five instances, always within the first hour after removal of catheters and has required only manual compression for control. In one child weighing less than 10 pounds laceration of a femoral artery by a faulty dilator tip required surgical exploration to repair the vessel. One child has required surgical femoral arterial embolectomy. In three instances, exploration of the groin was necessary to remove the severed tip of a wire guide. We have two patients in whom the catheterized extremity is shorter than the other. We have seen no instances of femoral arteriovenous fistulas (or false aneurysms) occurring after percutaneous catheterization, complications which have been reported in adults.9-12

Although the operators included several novices, an expert supervised each catheterization and intervened after a suitable period of unsuccessful effort by the trainee. The high rate of success in entry into vessels and in reaching desired sites with the catheter must be viewed in this light. By the same token, since some complications resulted from inexpert manipulations, the complication rate must be seen to be adversely weighted by the activities of trainees.

References
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