Percutaneous Heart Catheterization in Infants and Children

I. Catheter Placement and Manipulation with Guide Wires

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SUMMARY

This report describes in detail the materials and methods used in the authors' laboratory for percutaneous insertion of catheters and for manipulation of catheters with guide wires in infants and children. A simple thin-walled spinal needle is used to enter femoral vessels initially. Catheter insertion is effected thereafter with the sequential uses of a guide wire, a dilator, and an end-hole catheter. Insertion of two or three catheters into a single vessel may be accomplished. In infants weighing less than 20 pounds, dilation of the vascular puncture wound may be accomplished in stages. Guide wires of different configurations are used for catheter manipulation into various cardiac structures including some which are relatively inaccessible. Guide wires are also used for catheter exchange. Angiograms of high quality may be obtained safely.

Additional Indexing Words: Angiography End-hole catheters Seldinger technic

The results of our recent experience with the percutaneous technic of catheterization for hemodynamic and angiographic studies on 127 consecutive infants and children are presented in a companion report. The purpose of this paper is to describe in detail the materials and methods which are utilized in our laboratory. These represent our cumulative experience with approximately 2,300 cardiac catheterizations in infants and children performed since January 1, 1962, at Indiana University Medical Center and later at Childrens Hospital of Los Angeles, under the direction of P.R.L., who modified the technic of Seldinger for application in children.1, 2 Over the years additional refinements have been made in the method including multiple catheter insertion in a single vessel and several useful technics for catheter manipulation.

Methods

The following autoclavable materials are needed for percutaneous catheter insertion and for manipulation (fig. 1). Each item is briefly discussed.

The Needle

This is a simple thin-walled spinal type needle, such as B-D T462 LNR,* with a fitted stylet having a matched bevel point. More complex needles offer no advantages. The following is an approximate guide to choosing a needle in relation to the patient's weight:

<table>
<thead>
<tr>
<th>Weight (pounds)</th>
<th>Size (gauge)</th>
<th>Length (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infants 6-15</td>
<td>20</td>
<td>1.5</td>
</tr>
<tr>
<td>Children 15-35</td>
<td>19</td>
<td>1.5</td>
</tr>
<tr>
<td>35-60</td>
<td>18</td>
<td>1.5</td>
</tr>
<tr>
<td>Over 60</td>
<td>18</td>
<td>2.5</td>
</tr>
<tr>
<td>Obese adolescent</td>
<td>18</td>
<td>4.0</td>
</tr>
</tbody>
</table>

*Becton, Dickinson and Co., Rutherford, New Jersey.
The basic set for percutaneous insertion of 6 F catheters. (1 and 2) 18-gauge thin-walled needles (1.5 and 2.5 inches) with matched stylets. (3) A 0.035-inch guide wire. (4) A scalpel with a no. 11 blade. (5) A 19-gauge dilator tapered to the above wire. (6) A 6 F Teflon catheter.

For insertion of 5 F catheters one may substitute a 19-gauge thin-walled needle, 0.025-inch guide wire, and 20-gauge dilator tapered to the wire. For 7 and 8 F catheters, use the 18-gauge needles 0.035-inch wire, and larger dilators tapered to the wire.

In addition, a 21-gauge thin-walled, 1-inch-long needle with a short bevel is useful for entry into a very small artery. These needles must be sharp and free of burs.

The Guide Wire

This is a stainless steel close-wound, coil-spring wire with a core running through the full length except for about 3 cm at the tip. The core may be movable or fixed. A second fine safety wire lies within the coils and is soldered at both ends to insure against coil separation.* Wires of diameters ranging from 0.018 inches to 0.035 inches are available with the standard length of 125 cm. A 0.018-inch wire should not be used for catheter insertion; its tip is so delicate that it may be shorn off accidentally by the needle. The sizes of wires, needles, dilators, and catheters are matched as follows:

<table>
<thead>
<tr>
<th>Wire size (inch)</th>
<th>Needle size (gauge)</th>
<th>Dilator gauge</th>
<th>Catheter</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.021</td>
<td>20</td>
<td>22†</td>
<td>4 F</td>
</tr>
<tr>
<td>0.025</td>
<td>19</td>
<td>22</td>
<td>4 F</td>
</tr>
<tr>
<td>0.035</td>
<td>18</td>
<td>19</td>
<td>5 F, 6 F</td>
</tr>
<tr>
<td></td>
<td></td>
<td>16</td>
<td>7 F, 8 F</td>
</tr>
</tbody>
</table>

A standard guide wire may be bent near the tip into a desired curve to aid catheter manipulation.

In addition, a special guide wire with a ready-made J-shaped soft tip* is useful for manipulating a catheter through a sharply angulated passage (fig. 2). Each guide wire should be inspected prior to use for a kink, angulation, or coil separation. Defective wires must be discarded.

The Dilator

This is a piece of thin-walled radiolucent Teflon tubing 4 to 5 inches long. A tapered tip is best fashioned by heating the tubing over a Bunsen flame, pulling it to develop a narrow segment. A guide wire of proper size is advanced into the narrow segment until it stops and the taper is cut with a sharp blade just beyond the end of the wire, producing a very snug fit of wire within the tapered tip. An ideal dilator is straight, and the face of the tapered end is smooth and perpendicular to its long axis. For autoclaving and storage a short piece of discarded guide wire is placed inside each dilator to prevent warping. Use of the dilator prepares a path for the catheter and prevents damage to the catheter and the vessel. Radiolucent Teflon of which the dilator is composed combines superior surface lubricity and greater tensile strength than the radiopaque catheter and cleaves more closely to the guide wire.

The Catheter

Our cardiac catheters are made from thin-walled radiopaque Teflon tubing with high surface lubricity.* Each has an end-hole and 4 to 6 side-holes located on the distal 1 cm. Percutaneous catheters may be obtained from

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*Cook Inc., Bloomington, Indiana.
†Thin-walled.
commercial firms or made in the laboratory utilizing a commercially available catheter-forming tool.* The longest catheter should be shorter than the available guide wire by at least 15 cm. The tips of 4 F and 5 F catheters are tapered to 0.025 inches while 5 F, 6 F, 7 F, and 8 F catheters are tapered to 0.035 inches. Proper tapering is important for easy insertion into a vessel and prevention of lacerations of the vessel. Proper connection to the hub adaptor prevents leakage or rupture during pressure injection. In addition to the standard catheters described above, special purpose catheters are suggested. Catheters with only end-holes permit accurate localization of pressure gradients due to stenotic lesions. Radiolucent Teflon catheters are smoother, more blood-repellent, and probably less irritating than radiopaque catheters and thus are useful for implantation over several days in a central vein or a peripheral artery. Tips for special purposes may be baked on Teflon catheters by autoclaving them over styli of appropriate shapes.

In choosing the catheter sizes for a given patient, the operator must consider (1) the size of the patient, (2) anticipated difficulty of manipulation, and (3) whether or not angiography is of prime importance in the case. The greater the French size of the catheter, the stiffer it is and the more cumbersome it is for complex manipulations. On the other hand, a larger bore catheter is advantageous for angiography. A thin-walled catheter has an internal diameter approximately the same as that of a standard wall catheter that is one French size larger.

Catheter Insertion

Preparation of the Materials Prior to Catheterization

All the necessary items mentioned above are inspected for defects and for mutual compatibility. The guide wire must pass easily through the needle, the dilator, and the catheter. There must be a snug fit of the wire at the tips of the dilator and the catheter. They are placed close to the operative field for ready access (fig. 1). Catheters are flushed with heparinized saline. In addition, heparinized dilute saline is readied for cleaning the guide wires and flushing the catheters during the procedure.

Preparation of the Patient

After appropriate sedation, the patient is placed supine on the table and both inguinal areas are surgically cleansed. For most cardiac catheterizations, femoral vessels are preferred because of the straight course of the inferior vena cava into the right heart and because of the lack of severe vascular spasm immobilizing the catheter. Antecubital vessels may be used if necessary. Sterile towels are used to delineate the operative field. Slight abduction with external rotation of the thighs reduces the inguinal skin fold and renders the vessels more accessible to the operator. However, extreme “frog leg” positioning is undesirable.

Local Analgesia

Painstaking efforts are made to place adequate amounts of lidocaine strategically to prevent pain and vasospasm (fig. 3). A skin wheal is raised with 1% lidocaine 2 to 3 cm distal to the proposed vessel puncture site. Through this wheal additional amounts of lidocaine are delivered through a ½ inch needle both medial and lateral to the vascular sheath. If the procedure is prolonged, additional lidocaine may be necessary.

Puncture of the Femoral Artery and the Guide Wire Insertion

The key to successful insertion of an arterial catheter lies in precise puncture of the center of the femoral artery with the needle well aligned with the course of the vessel. The first step is to plot the course and depth of the artery by careful palpation. The artery is felt to take a relatively superficial course as it emerges from beneath the inguinal ligament. The artery is then felt to bend more deeply as it passes distally in the femoral triangle until it submerges into the adductor canal. The needle should be aimed for the point where this “bend” is felt. The needle is guided along an imaginary line which runs almost parallel to and directly over the artery and which, after penetrating the skin in the middle part of the femoral triangle, intersects the artery at an angle of 20 to 30°. Once the needle tip is under the skin, the stylet should be removed. When a pulsating jet of blood is encountered, the flexible tip of a guide wire is introduced through the needle into the lumen of the vessel. The wire should slide smoothly into the lumen. If resistance is encountered or the

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*Cook Inc., Bloomington, Indiana.

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The diagram of the femoral triangle area showing the locations of the blood vessels. Dotted lines mark the preferred sites for infiltration of lidocaine. (A) Frontal view; (B) right lateral view; AS = anterior superior iliac spine; IL = inguinal ligament; SM = sartorius muscle; AL = adductor longus muscle; RFA = right femoral artery; RFV = right femoral vein; GSV = great saphenous vein; PFA&V = profunda femoris artery and vein; N = needle.

Patient complains of pain, the wire must be withdrawn and the needle repositioned to obtain maximal flow. Sometimes retracting the needle slightly or rotating the hub 90 degrees in either direction may help to place the needle bevel totally within the vessel lumen. Frequently a novice operator tends to grasp the needle hub too firmly while attempting to pass the guide wire, causing the needle tip either to move inadvertently against the vessel wall or to kink the vessel preventing successful passage of the wire. If after reasonable attempts one fails to pass the wire guide, the needle is withdrawn and pressure is applied to the area of vessel puncture (for about 5 min) until bleeding stops completely before another puncture attempt is made. In some cases one obtains a distinct tactile sensation of the wire sliding in the vessel lumen for a short distance and then meeting abrupt obstruction. This may be due to tortuosity of the vessel or entry of the wire tip into a side branch. The situation may be remedied by manipulation of the wire under fluoroscopic control. If this fails, one may pass the guide wire as far up as it will go with ease along the main iliofemoral vessel and then proceed with dilation (described later) and catheter insertion. Afterwards, the catheter tip may be cautiously advanced under fluoroscopy aided by a flexible thin wire, a J-tipped wire, or injections of small amounts of contrast material. In general, it is not wise to allow a guide wire or catheter tip to wander into a small artery branch as this may result in potentially dangerous trapping of the wire or the catheter due to arterial spasm. Frequent fluoroscopic checking of the position of the catheter and wire helps prevent this complication.

Puncture and Guide Wire Insertion into the Femoral Vein

This technic is similar to arterial puncture except that the target is not palpable. The pulsation of the femoral artery or a catheter within the artery is used as the landmark. We prefer to catheterize the femoral vein before the artery since the femoral artery pulse seems to be a more easily recognizable reference point than a catheter within the femoral artery. Although the vein is found about 1 cm
medial to the artery in a patient weighing 40 pounds or more and this distance between the vessels tends to be less in smaller patients, this relationship is quite variable. In extreme cases, the vein may be found directly below the artery. Therefore, in looking for the vein one must systematically probe the area with the needle. Once the vein is penetrated, one sees a slow steady flow of venous blood from the needle. Both the color of the blood and its velocity of egress may be similar for the artery and the vein in a child with deep cyanosis and high hematocrit. In smaller patients or in those with very viscous blood, a syringe filled with saline solution may be attached to the needle hub and slight suction applied with the plunger. This helps in immediate recognition of entry into the vein. The caution and technic used to pass a guide wire into the artery also applies to the wire passage into the vein. Fluoroscopy is used to avoid accidental entry into locations such as a small peripheral vein or an atrial appendage, where further advancement without visual control may be hazardous.

Dilation and Catheter Placement

Once a guide wire is passed into the vessel for 15 to 20 cm and is smoothly movable, a scalpel with a no. 11 blade is slid along the needle shaft into the skin to widen the stab wound into a 2 to 4-mm nick depending on the size of the catheter to be employed. While a hand applies pressure over the site of vessel puncture, the needle is withdrawn over the wire which is held in situ. With practice the operator is able to apply compression with three ulnar fingers of his left hand and grasp the wire between the thumb and the index finger, while his right hand removes the needle. A novice operator should utilize an assistant for this step. The wire is cleansed of blood with gauze soaked in heparinized saline. The tapered end of a dilator is threaded over the guide wire. With a twisting motion the dilator is pushed through the vessel wall. Counter traction on the wire to prevent kinking is helpful at this moment. A popping sensation is felt as the dilator enters the lumen. The dilator is now removed and a catheter substituted after wiping the wire clean. Pressure should be maintained on the puncture site and the wire held stationary during the insertion.

Before the catheter is pushed under the skin, the operator must make sure that at least 1 cm of the guide wire is protruding from the hub of the catheter. The wire may have to be retracted to meet this condition. Otherwise, the wire cannot be retrieved after catheter insertion. A combination of pushing and rotating effects entry into the vessel. Again counter traction on the protruding end of the wire may be helpful. As soon as the catheter is in place, the location of its tip is confirmed by fluoroscopy. The wire is withdrawn, clots are evacuated by vigorous suction with a syringe, and the catheter is then filled with heparinized saline which is retained by a closed stopcock.

Catheter Exchange with Guide Wire

In the course of diagnostic studies, it may become desirable to use a different catheter from the one originally inserted. For example, after a small bore catheter has been manipulated into a location, a larger bore catheter is desired for angiography. The following procedure is useful for this purpose. After inserting a wire guide through the lumen, the existing catheter is removed over the wire and a new catheter substituted. Again compression is necessary to prevent bleeding. The end of the wire must be protruding from the hub of the new catheter before its tip is worked into the skin hole. If the replacement catheter is of smaller caliber than the original, blood may seep around the new catheter. A guide wire over twice the catheter length is helpful when one wishes to exchange catheters but does not want to relinquish a catheter position which is hard to obtain. Wire guides, 260 cm long, are available for this purpose.*

Catheter Exchange with Sheath

An ultra thin-walled Mylar* or polypropylene† sheath (which fits snugly over a

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*Cook Inc., Bloomington, Indiana.

†U. S. Catheter and Instrument Corp., Glens Falls, New York.
percutaneous catheter or a dilator) is advanced into the vessel over the catheter as described by Desilets and Hoffman. The catheter or dilator is then withdrawn and a closed-end catheter or pacemaker wire of the same outer diameter is advanced through the sheath. The sheath is then withdrawn and retracted to the hub of the new catheter.

**Multiple Catheter Technic in the Vein or Artery**

Two or sometimes three catheters may be placed percutaneously into a single vessel. Both a femoral artery and a femoral vein can accommodate two catheters each in children weighing over 30 pounds. In even somewhat smaller children, two catheters may be placed but only in the vein. There has been no increase in vascular complications due to multiple catheter technic, and it has simplified performance of selective dye curves, blood samplings, simultaneous pressure recordings, and angiography at a substantial saving in fluoroscopy time and catheter manipulation. When a second or third catheter is inserted, the same technic outlined previously is followed except that the skin and vessel punctures are made about 5 mm distal to the previous catheter, which serves as the landmark. The course of the needle is maintained exactly parallel to the first catheter to avoid impaling it.

**Graduated Dilation Technic**

This technic is useful for catheterizing infants weighing less than 20 pounds. A 20 or 21-gauge thin-walled needle is used to enter a vessel initially. A 0.021-inch guide wire is used as an initial guide. A 22-gauge dilator which is tapered to the diameter of this initial guide is inserted over it. This dilator is then replaced with a 22-gauge dilator which is tapered to a 0.025-inch wire. Once this second dilator is in, the first wire guide is replaced by a 0.025-inch wire guide. A third dilator, 20 gauge and tapered to a 0.025-inch wire, may be used next in an optional step. Then a 5 F catheter is inserted as the final step (fig. 4).

This technic combines the advantages of a small needle for entering a small artery and a reasonably large catheter for high fidelity pressure recording and high contrast angiography.

**Catheter Manipulation**

With the use of the guide wire for catheter insertion comes a bonus—an improved system of guiding the catheter. The Teflon catheter was found superior for guide wire technic because both inner and outer surfaces had higher lubricity and blood repellency than the time-honored nylon cardiac catheter. Teflon is, on the other hand, less elastic and more plastic than nylon. The nylon catheter permits only advancement, retraction, and rotation. If the baked-in curve of the nylon catheter is unfavorable for a given manipulation, one must either keep trying or replace the catheter. In contrast, the combination of the more plastic Teflon catheter with guide wires which may be used straight or bent as needed into various favorable curves provides an infinite variety of shapes without exchange of catheters. Merely altering the position of a curved wire within the catheter alters the configuration, while pulling the guide out and bending it differentially sets the stage for a new series of trials.

So guided, a catheter may be passed through an obstacle course of successive turns; for example, from the femoral vein through a hemiazygos vein into a left superior vena cava, thence via the coronary sinus into the right atrium, thence to the right ventricle and the
pulmonary artery. By this technic, such a passage becomes a matter of skill rather than a matter of chance. Manipulation of the wire-guided catheter must be learned as a new skill, since the two components may be moved together as a unit or separately either simultaneously or sequentially. To obtain full benefit from the many possibilities offered, the operator must try a maximal number of combinations with minimum of conscious effort and fluoroscopy time. All of this increased directive manipulation must remain within the usual bounds of safety from excessive arrhythmia and mechanical trauma. There are added sources of risk peculiar to guide wire manipulation: (1) If the catheter tip is engaged in a crevice in the myocardium or held against the vessel wall and the guide wire is pushed out through it, the ordinarily flaccid guide now becomes a stiff puncturing tool, braced by the catheter and unable to bend. Thus, the catheter tip must always feel and appear free-floating within a chamber or vessel before the guide wire is advanced. (2) The presence of the guide wire in the lumen encourages clot formation. Clot may form almost instantly near the start of the procedure, probably because of the tissue fluid which is adsorbed onto the wire during the introduction. Therefore, periods of catheter manipulation must be alternated with periods of catheter toilettage—removal of the guide wire, rapid forceful aspiration of the catheter, expression of the contents from the syringe onto gauze to check for clots, flushing of the catheter with heparinized saline, sealing of the catheter with a stopcock, and the cleaning of the guide wire just used with a sponge soaked in heparinized saline. One must develop almost an intuitive sense of timing as to how frequently these maneuvers should be undertaken for safety and economy.

**Catheter Configurations**

Five major configurations obtainable with a catheter alone, with a wire, or with a soft inner tubing will be described. These configurations are somewhat arbitrary. In general, in attempting to pass through an orifice the operator may manipulate the catheter and the wire independently until a configuration suited best for the particular situation is obtained.

1. **A Catheter Alone**

Gentle fixed curvature can be imparted to the catheter tip by stripping it between a thumb and index finger prior to inserting it into the vessel. Such a catheter may be used in the manners similar to any conventional cardiac catheter. Sharper, more permanent curves may be produced by autoclaving it over a curved metal stylus. Such a sharply curved catheter might be used for entering a branch vessel such as the renal vein.

2. **A Straight Wire Protruding Several Inches from the Catheter Tip**

This configuration produces a straight forward direction with improved flexibility. It is used for entering an orifice approximately in line with the main shaft of the catheter. For example, the superior vena cava or the coarcted segment of the aorta may be catheterized from the femoral region using this configuration. In these situations either the wire or the catheter alone may be manipulated independently of the other, or they may be moved as a unit.

3. **A Curved Wire Protruding from the Catheter Tip by Several Inches**

This gives infinitely variable angles of approach depending on the curvature of the wire and the length of the wire protruding from the catheter tip. The curve on a wire may be altered to fit the immediate need. This configuration aids in passing around the aortic arch from below, and can be useful for many other purposes as well.

4. **Curved Wire within the Catheter with its Soft Curved Tip Protruding 1 to 2 Inches**

This configuration gives a stiff catheter body with a relatively atraumatic flexible tip. It is used deliberately to create a loop in the catheter in order to reverse its curvature (fig. 5).

5. **A Catheter with a Small-Bore Polyethylene Inner Tubing**

Technic of entering the pulmonary artery using an atrial loop. (1) With the catheter tip in the right atrium (RA) adjacent to the tricuspid valve, a curved guide wire is manipulated into the right ventricle (RV). (2) With the bend of the curved wire against the anterolateral wall of RV, the catheter and the wire are pushed together until the part of the catheter in the RA begins to buckle in the right cephalad direction. (3) With further pressure from below, the bend of the catheter flips into a loop, reversing the curvature of the catheter tip. (4) A straight guide wire is used to guide the catheter tip into the pulmonary artery (PA). The atrial loop may be straightened out during this catheter passage.

There is no directional control of the tip of the tubing which simply “floats” into downstream location. This method was used in catheterizing the completely transposed pulmonary artery by Carr and Wells⁴ and is utilized for the same purpose in our laboratory with a high degree of success.

Some of these configurations may be further modified if one uses wires which are of smaller gauges than the one to which the catheter had originally been tapered. This will add to flexibility of the system rendering it less traumatic and adaptable to more tortuous or narrow passages. The following are actual laboratory situations in which one or more of the above configurations are combined to gain access to the desired vascular compartments.

**Venous Catheterization**

1. Entry into the superior vena cava from below: catheter alone or with a straight guide wire in advance.
2. Passage from the right atrium to the right ventricle: catheter alone (with a curved tip) or with a curved wire in advance.
3. Passage from the right ventricle to the main pulmonary artery: catheter alone; catheter with a straight wire; or creation of intra-atrial loop (fig. 5) followed by a straight or curved wire.
4. Passage from the right atrium to the left atrium via the patent foramen ovale: catheter alone or catheter with a straight or curved wire.
5. Passage from the left atrium into the left ventricle: catheter plus a sharply curved wire.
6. Passage from the left ventricle into the
Figure 6

Entry into the pulmonary artery (PA) in complete transposition of the great vessels. (1) The catheter tip is manipulated into the left atrium (LA) either by itself or with a guide wire. Then a curved wire is used to guide it into the left ventricle (LV). (2) The tip of the catheter should be turned cephalad. A PE-50 tubing (OD = 0.038 inches) is threaded through the catheter (5 F or 6 F).

(3) After the tip emerges from the catheter, the tubing is fed more slowly, allowing the blood current to carry it into PA. Contrast material filling the lumen of the tubing helps determine its course. A blood sample and pressure recording may be obtained through the coaxial tubing. Pulmonary arteriogram of poor quality may be made by injecting contrast material through the tubing. Alternate technique is to use a soft straight or curved guide wire to manipulate the catheter itself into PA.

catheter plus polyethylene tubing or catheter plus a curved wire to make a loop then a soft straight wire (fig. 6).

Figure 7

Entry into PA in corrected transposition. (A, upper panel) With ventricular septal defect (VSD). (1) The catheter is guided into the ascending aorta (AA) and the functional left ventricle (LV) with a curved wire. (2) The curved wire is manipulated into VSD and PA. (3) The catheter is advanced over the wire into PA.

(B; lower panel) With intact ventricular septum. (1) The catheter is guided into the right ventricle with a curved wire. (2) Using the tightly formed curvature in the wire, the catheter is looped within the right ventricle. (3) A straight wire is used to enter PA. The catheter is advanced over the wire.
7. Entry into the renal or suprarenal vein: special catheter with a baked-in curved tip.
8. Entry into the pulmonary artery in corrected transposition:
   a. In the presence of a ventricular septal defect: with a retrograde arterial catheter aided by a curved guide wire (fig. 7A).
   b. With an intact ventricular septum:
      (1) With the catheter forming a clockwise loop in the venous ventricle (fig. 7B)
      (2) From the left arm with a curved guide wire.

**Arterial Catheterization**

1. Passage through coarctation of the aorta: catheter plus a straight guide.
2. Passage around the aortic arch: with a curved wire. A guide wire with a J-shaped soft tip is useful for this purpose (fig. 8).
3. Passage into the left ventricle: catheter and a wire with a curve (made in the distal part of the core). Allow the wire tip to be captured below the closing aortic valve. A wire with a J-tip may hinder this maneuver (fig. 8).
4. Passage into the brachiocephalic branches: catheter alone or in combination with straight and curved wires.
5. Retrograde passage from left ventricle to left atrium: curved wire with the patient in right anterior oblique projection. A guide wire and catheter with an S-shaped curve may be helpful (fig. 9).

**Management of Complications**

Use of guide wires during catheter insertion and manipulation predisposes to thrombosis within the catheter. Frequent flushing can

**Figure 8**

Retrograde entry into the ascending aorta (AA) and LV. (1) With the catheter in the descending aorta, a curved guide wire or a J-tipped wire is advanced into AA. The catheter is advanced over it. (2) The bend of the curved wire is placed in the right sinus of Valsalva. To enter LV from AA, a J-tipped wire is not helpful and should be replaced by an ordinary curved wire.

(3) The wire is withdrawn and at the same time the catheter tip is advanced over the wire slowly. As the catheter tip passes over the bend of the wire, the net effect is to straighten out the curvature of the wire, thus producing some downward tension against the right cusp and splinting of it in the closed position.

(4) With a subsequent systole, the left and noncoronary cusps open and the wire tip springs into LV.

**Figure 9**

Retrograde entry into LA from the aorta using an S-shaped guide wire and catheter.

Both catheter and guide wire have a preformed S curve. The slight curve assumed by an ordinary catheter and wire rounding the aortic arch and entering the left ventricle tends to point anteriorly toward the apical portion of the left ventricle. With the S, the more proximal portion of the catheter tip retains this direction, but then the catheter curves down, back, and upward, bypassing the apex and pointing toward the mitral valve. (1) With the catheter in the AA, a guide wire with an S-shaped tip is passed into LV. (2) With the patient in the right anterior oblique position the tip of the S is manipulated into LV and into LA. (3) The catheter is advanced over the wire.
Percutaneous Heart Catheterization

forestall this process. In the event that the catheter becomes occluded with a clot, the following procedure may be worth trying before the catheter is removed completely as a last resort. A small (2 cc) syringe is filled to about 0.2 cc with normal saline, and is connected securely to the catheter in question. The catheter is withdrawn downstream from the important arteries such as the coronary, carotid, and renal arteries. A gradually increasing pressure is applied to the syringe plunger until the operator feels a “give.” The plunger is now pulled back forcefully. Once the clot has been loosened, a series of quick aspirations with a larger syringe usually removes all fragments of the clot. A guide wire should never be pushed into a catheter lumen known to be clotted.

After the conclusion of study, distal pulses in the lower extremity may be diminished. A great majority of these cases improve spontaneously within 24 hours. In some cases, the pulse return is delayed up to several weeks. In our experience, only two patients have had permanent vascular complications, including leg shortening in both and avascular necrosis of a tarsal bone in one. Those patients underwent percutaneous arterial catheterization at ages 1 mo and 8 mo, respectively.

Angiography

To minimize the chance of catheter recoil or intramyocardial injection of contrast material, care is taken to place the catheter tip so that the following conditions are met: (1) ECG remains relatively stable with no more than occasional isolated ectopic beats present; (2) The catheter tip is freely swinging within the chamber judged by fluoroscopy; (3) A small test dose of contrast material injected at the same pressure as the proposed power injection neither stains the myocardium nor enters a coronary or carotid artery as an undiluted bolus nor causes recoil of the catheter out of the desired site. We have been able to use injection pressures similar to those used with closed-end catheters for rapid delivery of enough contrast material to produce angiograms of high contrast.

Catheter Removal and Aftercare

After the conclusion of the diagnostic study, the catheters are removed. Firm pressure is applied immediately to the area where the blood vessels were punctured. Skin holes need not be covered. Five to 10 min of compression is usually sufficient for complete cessation of bleeding. The wound is then observed for a few minutes, before it is dressed with an absorbent dry dressing. The patient is observed for changes in vital signs and for bleeding or hematoma from the wound. Usually, rest in bed for 4 to 8 hours is sufficient before the patient is allowed to ambulate. The catheters are checked for the presence of small clots immediately following the removal from the patient. Our recent survey indicates a significant correlation between presence of the clots in the arterial catheter and delay in return of distal pulses.

Our patients are usually ambulating normally and are discharged from the hospital 12 to 18 hours after the study. In most cases, scars from the percutaneous catheter insertion are difficult to see 6 to 8 mo later. The same artery and vein may be used again for a second or third cardiac catheter if necessary.

Processing of Materials after Their Use

Needles, catheters, and stopcocks are disassembled, thoroughly flushed with tap water, cleansed with detergent-antiseptic, shaken in an ultrasonic bath, flushed with distilled water and autoclaved.

Guide wires are preferably discarded after a single use. If they appear upon careful inspection to be mechanically perfect, they must be subjected to prolonged ultrasonic shaking and flushing as their interstices hold blood with great tenacity.

Dilators cost little. They may be discarded or re-used if there is no deformity after use.

Discussion

The percutaneous guide wire technic of catheter insertion and manipulation described here has been shown in a companion paper to combine advantages such as: (1) rapidity of catheter placement and removal; (2) accessi-
bility to many cardiovascular structures; (3) possibility of multiple catheters in a single vessel; (4) ease of aftercare (and patient satisfaction); (5) low incidence of complications; and (6) re-use of the same vessels for later procedures. From our own experience, skill in this technic cannot be acquired overnight. Indeed, proficiency in conventional cutdown technic and catheter manipulation without guide wires is no guarantee of facility with this method from the outset. We strongly believe that for the maximum safety to the patient and for the fastest acquisition of skill, the beginner should seek coaching and supervision by someone who is already proficient rather than resort to unsupervised trials which may prove to be frustrating, wasteful, and hazardous.

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References

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MASATO TAKAHASHI, EUGENE L. PETRY, PAUL R. LURIE, STANLEY E. KIRKPATRICK, CAPT., U.S.A.F., MC and ROBERT E. STANTON

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