Coronary Arteriography by the Single Catheter
Percutaneous Femoral Technique
Experience in 6,800 Cases

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SUMMARY
A new percutaneous femoral method for studying the coronary arteries, left ventricle and saphenous vein bypass grafts using a single catheter has been developed. A #8 French 100 cm polyurethane catheter with wire incorporated and a 45° curved tip has been used in 6,800 patients. This technique combines the speed and simplicity of the percutaneous femoral approach with the safety of the single catheter technique by eliminating multiple catheter and guidewire changes. Manipulation techniques for selective right and left coronary artery and saphenous vein bypass graft injections as well as for left ventriculography are described. In only 10% of the cases has it been necessary to change to a second catheter, and catheterization time has averaged less than 15 minutes. Complications have been infrequent: femoral thrombosis 0.3%, hematoma 0.2%, myocardial infarction 0.04%, cerebrovascular accident 0.03% and death 0.07%. The speed of the technique and the elimination of multiple catheter changes seem to have contributed to the low complication rate.

Additional Indexing Words:
Coronary catheterization
Catheterization

RADIOGRAPHIC VISUALIZATION of the coronary circulation adds another dimension to clinical medicine by providing information in living man obtainable in no other way. Of the two generally used methods the arterial cut-down technique as described by Sones¹ has been proven a safe, reliable method for studying the coronary circulation but requires an antecubital dissection, arteriotomy, wound closure and suture removal. The second commonly used technique employs the percutaneous femoral approach which obviates the need for a cut-down, arteriotomy and follow-up care, but as generally applied requires the use of three preformed catheters in order to study the right and left coronary arteries as well as the left ventricle.²-⁷ These femoral techniques can be performed with much less training but in some hands have been associated with a higher incidence of life threatening embolic complications.⁸-¹¹ The purpose of this communication is to describe a technique for selective coronary arteriography and left heart catheterization which combines some of the advantages of the most commonly used methods.

A single catheter inserted by the percutaneous femoral approach is used to selectively catheterize the right and left coronary arteries as well as the left ventricle. The goals of excellent visualization of the coronary anatomy and left ventricular function, speed and simplicity in application and a high degree of patient safety have been accomplished. Six thousand eight hundred patients have been studied in the past 7 years. Approximately 40% of these were referred in order to establish or rule out major coronary obstructive disease. The other 60% had clear-cut angina pectoris and were studied to select candidates for coronary bypass surgery. Study by this technique was denied if recent myocardial infarction was suspected, except in cases where immediate direct coronary bypass surgery was anticipated, or in patients who were excessively anticoagulated with coumadin. The femoral approach was not used in patients in whom there were no pulses palpable below the femoral artery; however, neither a bruit in the femoral artery nor the size of the patient has been a contraindication to study by the percutaneous femoral technique.

Material and Methods

Catheter Design
The catheter characteristics required are good torque control, memory qualities, and adequate tip flexibility to
enable a loop to be formed for entry into the left coronary orifice and enough stiffness to hold the tip against the anterior aortic wall for right coronary artery and vein bypass visualization. The lumen must be adequate to handle a moderately large flow rate for left ventriculograms. Side holes are required to minimize recoil on left ventricular injections. A single 45° curved tip seems optimal. One hundred cm length is needed and a #8 French size provides the best torque control. Several catheters were tried initially, but the most satisfactory one available is made of polyurethane with wire incorporated* (fig. 1). These catheters are for single use only. The woven dacron catheter† is also satisfactory but has poorer plastic memory qualities needed for right coronary artery catheterization. Polyethylene catheters have been tried but they have a tendency to whip on rotation and have therefore proved inferior.

Catheterization Technique

The catheter is introduced percutaneously from either the right or left femoral artery by the Seldinger technique.* It is advanced over a 0.35 teflon coated guidewire with floppy tip into the abdominal aorta only. The guidewire is removed at this point and the catheter is flushed vigorously with saline. Because of the gentle curve on the catheter tip it may be advanced around the aortic arch without using a guidewire. Four thousand units of heparin are added to the 500 cc of saline used for the flush line. Most patients receive 100 to 200 cc of this during a procedure. Systemic heparinization has not been used.

Catheterization of the Left Coronary Artery

It is helpful in catheterizing the left coronary artery first to position the tip in the noncoronary cusp. To accomplish this the patient is moved to the 30° right anterior oblique position which puts the noncoronary cusp most posterior toward the spine. The catheter is then advanced with the tip pointed toward the spine so as to enter the noncoronary cusp (fig. 2). By gently advancing the catheter a loop will begin to form with the tip of the catheter pointed toward the spine. As the loop increases the catheter will flip with the tip coming to lie in the left coronary sinus and the body of the loop lying along the anterior medial portion of the aortic root. A slight amount of clockwise rotation on the catheter frequently enhances the proper lateral flip of the catheter tip. If, when the loop is formed, the catheter tip does not flip into the area of the left coronary cusp it usually will lie more posterior. In this case continued rotation of the catheter clockwise will bring the tip to the plane of the left coronary orifice. If the tip is riding higher than the orifice, slight withdrawal of the catheter will cause the tip to fall onto the belly of the left coronary cusp. At this point slight rapid advancing of the catheter will hold the tip on the left cusp and continued advancing of the tip will bring it up to the level of the left coronary orifice (fig. 3). On occasion the tip may ride up anterior to the left coronary orifice in which case it will be necessary to apply counter-clockwise rotation as the tip is advanced. With the tip of the catheter lying at the left coronary orifice, slight withdrawal of the catheter will cause the bore of the catheter to align itself with the coronary orifice. Because the catheter is tapered very little and because of the orientation of the left coronary orifice the catheter does not enter the left coronary artery, but rather lies directly at the mouth of the artery enabling good selective opacification.

* Cordis Ducor Multipurpose A2 100 cm.
† U.S. Catheter Corporation — Sones Positrol.
CORONARY ARTERIOGRAPHY TECHNIQUE

Figure 3
Catheter manipulation for the left coronary in the 30° RAO view. The tip is slowly advanced off the left coronary cusp with counter-clockwise rotation until it rises to the left orifice.

Points of Difficulty with Left Coronary Catheterization

As the initial loop is being formed in the noncoronary cusp, in some patients with larger aortic roots the catheter may tend to fall into the left ventricle prematurely. A quick but modest withdrawal of the catheter at the time the flip is anticipated will produce the desired loop with the tip coming to lie in the left coronary sinus. If the tip does fall into the ventricle, several passes at forming the loop should be made in rapid succession with quick withdrawal of the tip at the time of the anticipated flip, usually facilitating formation of the proper loop. If this proves unsuccessful the catheter tip may be advanced onto the left coronary cusp directly. Advancing the catheter with counter-clockwise rotation will many times result in the loop as described above.

When the left coronary orifice lies very high in the coronary sinus or above the sinotubular ridge, catheterization will be more difficult. As the catheter is advanced toward the orifice the tip will pull away from the aortic wall before coming to the orifice of the left coronary artery. If this is the case, attempts should be made at forming a larger loop before this technique is abandoned. In 9% of cases the left coronary artery has been situated so that, although it could be opacified, excellent visualization could not be obtained. In these instances a preformed left coronary catheter was used. Because of the shape of the aortic arch the catheter assumes a gentle curve around the aortic arch into the anterior medial portion of the aortic root and up to the more posterior lateral portion where the left coronary orifice lies. The catheter is more stable when located at the left coronary orifice than when the right brachial artery approach is used. Since the catheter does not directly enter the left coronary artery it does not significantly decrease flow, enabling multiple views to be obtained without removing the catheter from the left orifice. All injections are monitored visually to assure that run-off from the left coronary system is rapid. Catheterization of patients with aortic stenosis or regurgitation and enlarged aortic roots has posed no special prob-

Figure 4
Catheter manipulation for the right coronary in the 60° LAO view. Clockwise rotation brings the tip to the right orifice.

lems except that a larger loop must be formed to reach the left coronary orifice.

Right Coronary Artery Catheterization Technique

With the patient in the 45° to 60° left anterior oblique view the catheter is positioned in the left coronary cusp. It is withdrawn slightly and by clockwise rotation the tip is directed along the anterior wall of the aortic root until it comes to lie at the orifice of the right coronary artery (fig. 4). The take-off of the right coronary artery is quite variable, and in some cases in which it is oriented inferiorly the catheter will deeply enter the artery. When this occurs the injection is accomplished and the catheter removed immediately. This same maneuver may be accomplished with the patient in other degrees of obliquity, although the left anterior oblique view puts the right coronary orifice on tangent and facilitates its catheterization. The torque control and good memory qualities of the polyurethane catheter as well as its preformed 45° curved tip make this catheter well suited for entering the right coronary artery. As the catheter is rotated anteriorly slight lengthening occurs so that it is advisable to start the rotation somewhat higher than the anticipated level of the right coronary orifice. If difficulty is encountered in entering the right orifice because of a very high location on the right coronary sinus or a marked superior orientation of the right coronary artery, then an alternate approach may be used. Once again the tip is rotated into the right coronary sinus, and the catheter is slowly advanced. This results in a loop being formed with the belly of the catheter coming to lie in the left coronary sinus. As the catheter is advanced the tip will gradually rise in the right coronary sinus until it reaches the level of the right coronary orifice (fig. 5).

Figure 5
Catheter manipulation for the right coronary in the 60° LAO view. The tip is slowly advanced off the right cusp until it reaches the right orifice.
Catheter position in the left ventricle in the 30° RAO view.

Left Ventricular Catheterization

The polyurethane catheter is well suited for crossing the normal aortic valve and does so with ease. The catheter should be positioned in mid ventricle with the tip parallel to the long axis of the left ventricle (fig. 6). When premature ventricular contractions occur very slight counter-clockwise rotation will bring the catheter tip away from the septum and usually result in termination of the arrhythmia. Careful attention must be paid to avoiding catheter positions too near the apex or against the left ventricular wall in order to prevent intramyocardial injections. Likewise the catheter should not be positioned too high in the left ventricle because it will recoil out of the ventricle when power injections are made. A small flush injection of contrast media is mandatory to check the position of the catheter tip. Power injections can be accomplished with a modest flow rate and slow rise time using from 8 to 10 cc per second for 4 seconds with good visualization of the entire left ventricle and minimal arrhythmia problems. Ventriculograms in our institution are normally performed prior to coronary artery catheterization, enabling left ventricular pressure measurements to be made before injection of any contrast media.

Catheterization of Saphenous Vein Bypass Grafts

Because the saphenous vein bypass grafts are attached to the anterior portion of the aorta these are accessible to easy catheterization with the same catheter as described. With the patient in the high left anterior oblique view the radio opaque markers used to identify the coronary bypass grafts can easily be seen on tangent. By positioning the catheter just above the aortic anastomosis and rotating the catheter gradually clockwise the tip can be brought to the orifice of the bypass grafts as shown in the right anterior oblique view in figure 7. For superiorly oriented grafts the catheter can be advanced forming a loop which will enter the graft directly. The innominate artery and the left subclavian artery can be easily entered and in many instances the internal mammary artery can be directly catheterized. Frequently, however, a specialized preformed catheter is required for selective visualization of the internal mammary bypass grafts.

Results

Catheter time has averaged 14 minutes. Major complications in the 6,800 patients are summarized in table 1. There have been only seven unsuccessful procedures, no infections, no arterial dissections and no arterial venous fistulae, although right heart catheterization was performed from the femoral vein in the same leg in 20% of the 6,800 cases. Complications fall into two general categories: 1) local
Table 1
Complications in 6,800 Cases

<table>
<thead>
<tr>
<th>Complication</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femoral arterial occlusion</td>
<td>22</td>
<td>0.3</td>
</tr>
<tr>
<td>Hematoma</td>
<td>16</td>
<td>0.2</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>3</td>
<td>0.04</td>
</tr>
<tr>
<td>Cerebrovascular accident</td>
<td>2</td>
<td>0.03</td>
</tr>
<tr>
<td>Mortality</td>
<td>5</td>
<td>0.07</td>
</tr>
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</table>

The femoral and 2) cardiac and cerebral complications. The femoral complications have been infrequent and have been easily handled. Twenty-two patients may have undergone femoral thrombectomy with a Fogarty catheter following thrombotic occlusion of the femoral artery. All of these patients have had successful return of pulses without any continuing ischemia of the leg. Femoral artery occlusion was more common in small female patients and in patients with low cardiac output. Hematoma formation of a significant degree occurred in 16 patients but required evacuation in only four. Patients predisposed to hematoma formation were those with systemic hypertension and those on anticoagulants. Myocardial infarction occurred as a direct result of the procedure in only three patients and cerebrovascular accident in two. Both patients with the cerebrovascular accidents and one with acute myocardial infarction probably had dislodgement of thrombotic material from the catheter. Multiple catheters were used in each of these three cases. Five patients died as a result of the procedure, accounting for an over-all mortality of 0.07%. One death occurred in a patient with tight aortic stenosis who developed supraventricular tachycardia which could not be cardioverted, leading to low output and death. Postmortem examination showed severe three-vessel coronary artery disease as well as severe calcific aortic stenosis. No embolic material was found in the coronary arteries. One patient with severe three-vessel disease died after insertion of a balloon pump catheter while being readied for coronary bypass surgery. At postmortem examination a thrombus judged to be 5 to 7 days old was found in the left main coronary orifice. A third death occurred in a patient who had a high left coronary orifice. Multiple catheters were used in an attempt to catheterize this vessel, and following injection through a preformed left coronary catheter the patient developed chest pain, acute ST elevation, fall in systemic arterial pressure and ventricular fibrillation from which he could not be resuscitated. At postmortem examination a catheter thrombus was found occluding the left main coronary artery. The fourth death occurred in a patient who developed bradycardia and hypotension upon insertion of the catheter into the femoral artery. Resuscitative attempts were unsuccessful and the patient died before the coronary ostia were catheterized. At postmortem examination the left as well as right coronary orifices were found to be narrowed to less than 1 mm. The final death occurred in a patient who underwent uneventful coronary arteriography and left heart catheterization which revealed severe three-vessel coronary artery disease. Upon leaving the catheterization laboratory the patient developed severe chest pain and hypotension from which he could not be resuscitated. Postmortem examination showed severe involvement of all three major coronary arteries without thrombotic material being found. Life threatening complications of coronary arteriography seem to be related to 1) dislodgment of thrombotic material from the catheter tip, or 2) peripheral vasodilatation resulting in an acute decrease in coronary filling pressure in patients with critically situated lesions. Embolic complications have received considerable attention in literature. An important point from our experience is the fact that all patients with documented embolic complications have undergone multiple catheter changes. No major embolic problems have been seen in patients who have had successful catheterization with the single catheter as described. Complications due to the acute decrease in systemic resistance seem unrelated to catheter technique although the result can be equally disastrous. We have adopted the practice of having vasopressors immediately available for use at the first sign of significant hypotension. The early use of vasopressors has been important in preventing complications in several patients with left main coronary stenosis who had transient hypotension.

Discussion

Selective coronary arteriography has added greatly to the understanding of coronary artery disease. Recently the procedure has been used liberally as a diagnostic tool to establish or rule out the diagnosis of coronary atherosclerosis as well as an anatomical map in planning coronary bypass surgery. As indications for study are liberalized a high priority must be placed on the cost of the procedure in terms of patient safety and efficiency as well as on diagnostic accuracy. The method described combines some advantages of the existing techniques.

The percutaneous technique developed primarily because of the entry of radiologists familiar with this approach into the field of heart catheterization. It has, however, become popular with cardiologists as well because it is less time consuming than the brachial approach, allowing for more efficient use of
physician and laboratory time and because local complications are less.8

Although local complications are reduced recent reports indicate that some angiographers have had a higher incidence of the more serious cardiac complications using the multi-catheter femoral techniques.9-12 However, with the single catheter percutaneous femoral approach our complication rate has been extremely low. Takaro9 suggests that the use of multiple catheters inserted over guidewires may account for the high embolic complication rate experienced by some. He postulates that withdrawal of the catheter from the femoral puncture site deposits surface thrombus material which may be picked up by the next catheter inserted and become the source for coronary or cerebral embolization. Indeed, most embolic events reported have occurred after a second or third catheter was inserted. When a single catheter is used there is no opportunity for pick-up of withdrawal thrombus. In the 10% of patients who require a second catheter, careful flushing and vigorous manipulation of the catheter tip is accomplished in the descending aorta below the diaphragm before traversing the arch. The guidewire is used only for introduction of the catheters and is never advanced around the arch.

The method described relies on cine angiographic techniques which, with newer high resolution X-ray equipment, give adequate diagnostic information. In order to insure that the catheter does not occlude or intrude deeply into the coronary artery, the catheter tip is visualized at all times. When cine angiographic techniques are used the catheter can be brought to the orifice of the coronary artery, the injection made and the catheter withdrawn in a few seconds, thereby inducing as little change as possible in coronary flow.

Pullback injections allow good visualization of the orifice. By watching the negative washout of contrast media a rough index of coronary flow can be made. We have seen several episodes of failure of contrast material to clear from the coronary artery due to vasospasm. If this vasospasm is distal to the catheter tip damping of the pressure contour may not occur and therefore the hold-up of contrast media may not be detected if the pressure contour is the only parameter monitored. We have also found that during direct visualized injections the volume injected into the coronary arteries need only be 2 to 6 cc. The major disadvantage of the single catheter percutaneous technique is that, like the Sones technique, skill in catheter manipulation and thorough familiarity with the anatomy of the aortic root are required. Operators familiar with the Judkins catheters will find that some patience in the learning phase is required to perform the technique with a single catheter. Those accustomed to the Sones approach will find the manipulation similar. Approximately 1,800 of the 6,800 cases have been performed by cardiology fellows. Although most of them have required 40-100 cases to gain proficiency in the technique, once mastered it has provided a rapid and safe approach to the study of the coronary arteries and left ventricle.

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