Selective Coronary Arteriography

Part I: A Percutaneous Transfemoral Technic[1]

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Until recently, there has been a reluctance to subject the coronary patient to the "added risk" of coronary arteriography. The recognition that coronary arteriography is no more hazardous than selective cardioangiography, that coronary visualization can depict precisely the presence and extent of disease, and that something can be done about coronary artery occlusive disease has extended the indications and increased the demand for detailed coronary delineation.

Numerous technics for coronary visualization have been proposed (2, 4, 5, 8–11). In general, the various forms of the aortic root flush have been favored in Europe, while more selective technics have gained acceptance in the American centers.

The new technic reported here facilitates consistent, rapid selective catheterization of both coronaries with a minimum of catheter manipulation; takes advantage of the ease, rapidity of performance, and low complication rate of percutaneous femoral catheterization; facilitates both direct serial and ciné filming; and is readily taught to residents, fellows, and practicing angiographers.

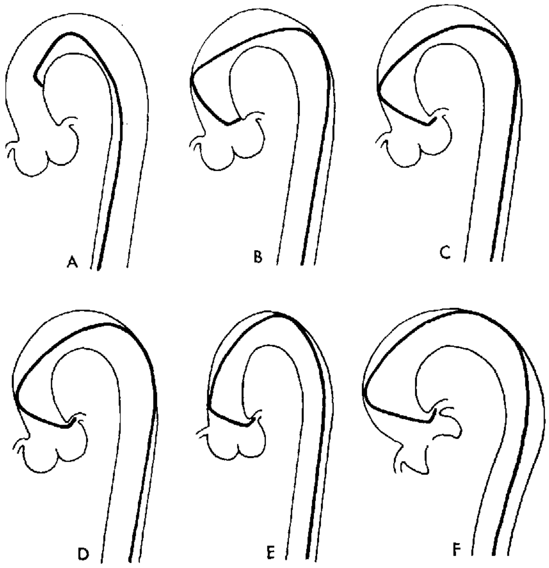

Fig. 3. *Left Coronary Catheter Technic.* The guide is removed as the catheter is advanced through the proximal descending thoracic aorta. A. The catheter is maneuvered to a "relaxed" position in the aortic arch, cleared, and the patient turned 20° RPO. B. Catheter is advanced slowly until (C) it drops into the coronary orifice. The spring afforded by the secondary bend holds the tip in the coronary orifice.

D, E, and F. Catheter position and the reason for "catheter arms" of varying lengths when used in (D) medium, (E) small, and (F) poststenotic (large) aorta.

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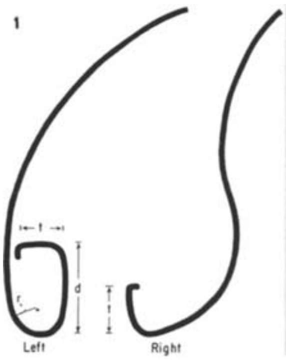

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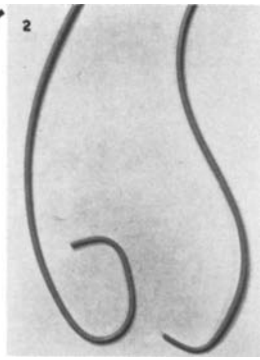

Fig. 1. *Catheter Bending Wires.* Bending wires are formed (from 0.038-in. stainless steel spring wire) into the above shapes. *Left:* d = 4 cm (medium size), 5.0 cm (large size), or 3.5 cm (small size); t = 2 cm; r = 1.1 cm. The primary angle is 90°, the secondary 180°, the radius of curvature of the tertiary curve about 10 cm. *Right:* t = 1.5 cm (medium size), 1.0 cm (small and large size); the secondary curve is 135° and has a radius of 5 to 6 cm (small and medium sizes) or 10–12 cm (large size).

Fig. 2. *Left and Right Coronary Catheters.* The tips are 5.5 F and have an I.D. of 0.041 in. The body is 8F with an I.D. of 0.056 in., and a 12-strand braid of stainless steel wire is incorporated into its wall. The braid insures good torque control.

MATERIAL

One hundred consecutive patients between the ages of twenty-one and sixty-nine years were examined for suspected coronary disease. In each, both coronary arteries were selectively catheterized from

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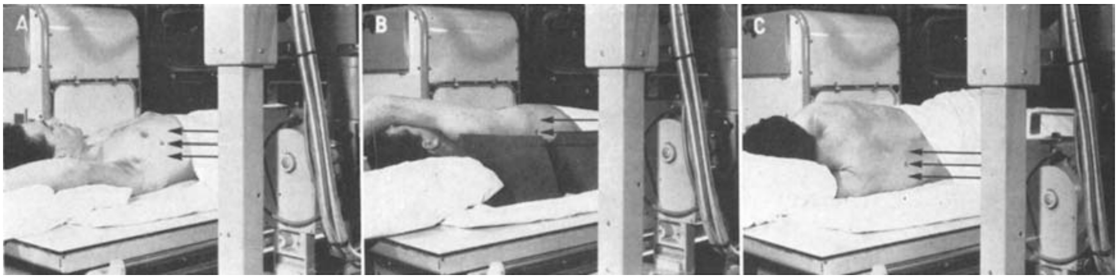


Fig. 4. *Radiographic Positioning.* (A) Lateral, (B) LAO 70°, (C) RAO 20°, to the lateral changer. All films are taken single plane, with a horizontal beam. Technical factors: 1,000 mA, 0.010 sec. (10 mAs); 80-95 kV; 38-in. distance; high-speed screens; Kodak Royal Blue film; 12:1 100 line grid; 1-mm spot—Dynamax 61 tube.

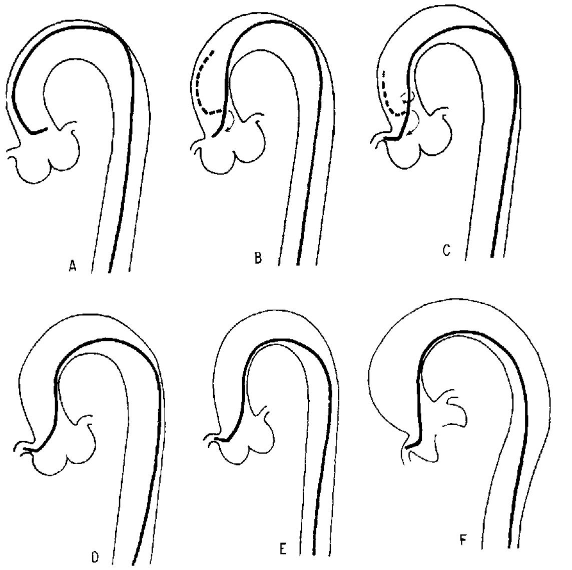


Fig. 5 (above). *Right Coronary Catheter Technic.* The catheter is advanced (A) to a point about 2-3 cm above the left coronary orifice, then rotated (B) *slowly* 180° until it drops (C) into the right coronary orifice. The curve of the aortic arch causes the catheter to descend in the ascending aorta as it is rotated. If the catheter does not enter the right coronary on the first try, the level of rotation should be adjusted up (if the catheter tip descends deep into the sinus of Valsalva) or down (if the tip rotates above the lip of the right coronary sinus) as indicated.

D, E, and F. Catheter position and configuration in (D) medium, (E) small, and (F) poststenotic (large) aortas. Note that the primary curve is decreased to about 70° and the secondary curve is flattened for the enlarged aorta.

the femoral artery, and contrast injections were filmed by direct serial radiography and cinephotofluorography. Over one-third of the patients were examined on an outpatient basis.

TECHNIC

Initially two 100-cm 8F Ducor catheters[2] (12) were shaped over preformed stainless steel bending wires (Fig. 1). The original configuration was removed, and a new one set by heating in boiling water for about two minutes.

This basic Ducor catheter (a polyurethane catheter with internal stainless

[2] Ducor is the trademark of Cordis Corp., 125 N. E. 40th St., Miami, Fla.

Fig. 6 (*opposite page*). *Serial Films of Selective Contrast Agent Injection in the Left and Then the Right Coronary Artery are Taken in 3 Projections:* RAO 20°, LAO 70°, and left lateral. Multiple projections are essential if all portions of the coronary system, splayed over an egg-shaped surface, are to be fully evaluated. The views selected give perspective and depth to the coronary anatomy.

A. Left coronary, RAO. The origin ↑, the proximal portion of the anterior descending †, and the distal circumflex system ‡ are well outlined.

B. Left coronary, LAO. In this view you are looking directly at the apex of the heart. The position of the 4 major left coronary vessels (the anterior descending ↑, its major branch, the diagonal †, and the circumflex ‡ with its obtuse marginal branch ↑) are best seen in relation to true apex. The septum is observed on end, and the left main coronary artery is foreshortened.

C. Left coronary, lateral. The proximal portion of the circumflex branch ‡ is in profile. Anteroposterior relationships of the peripheral part of both systems are clearly shown.

D. Right coronary, RAO. The mid portion of the right main coronary artery ↑, its acute marginal branch †, and the posterior descending branches ‡ are seen in profile.

E. Right coronary, LAO. The right main coronary artery ↑ is well seen. This view demonstrates the anatomy of the crux and the adjacent vessels, except for the posterior descending branch ‡, which is seen on end. This LAO view best visualizes the vascular ring that marks the atrioventricular groove. The right main coronary artery, its posterior branches, and the circumflex branch of the left coronary outline and complete the circle.

F. Right coronary, lateral. Proximal portions of the right ventricular vessels ↑ and the anteroposterior relationship of the right coronary system are shown. Note the small atheroma of the proximal right coronary not visible in the RAO view ↑.

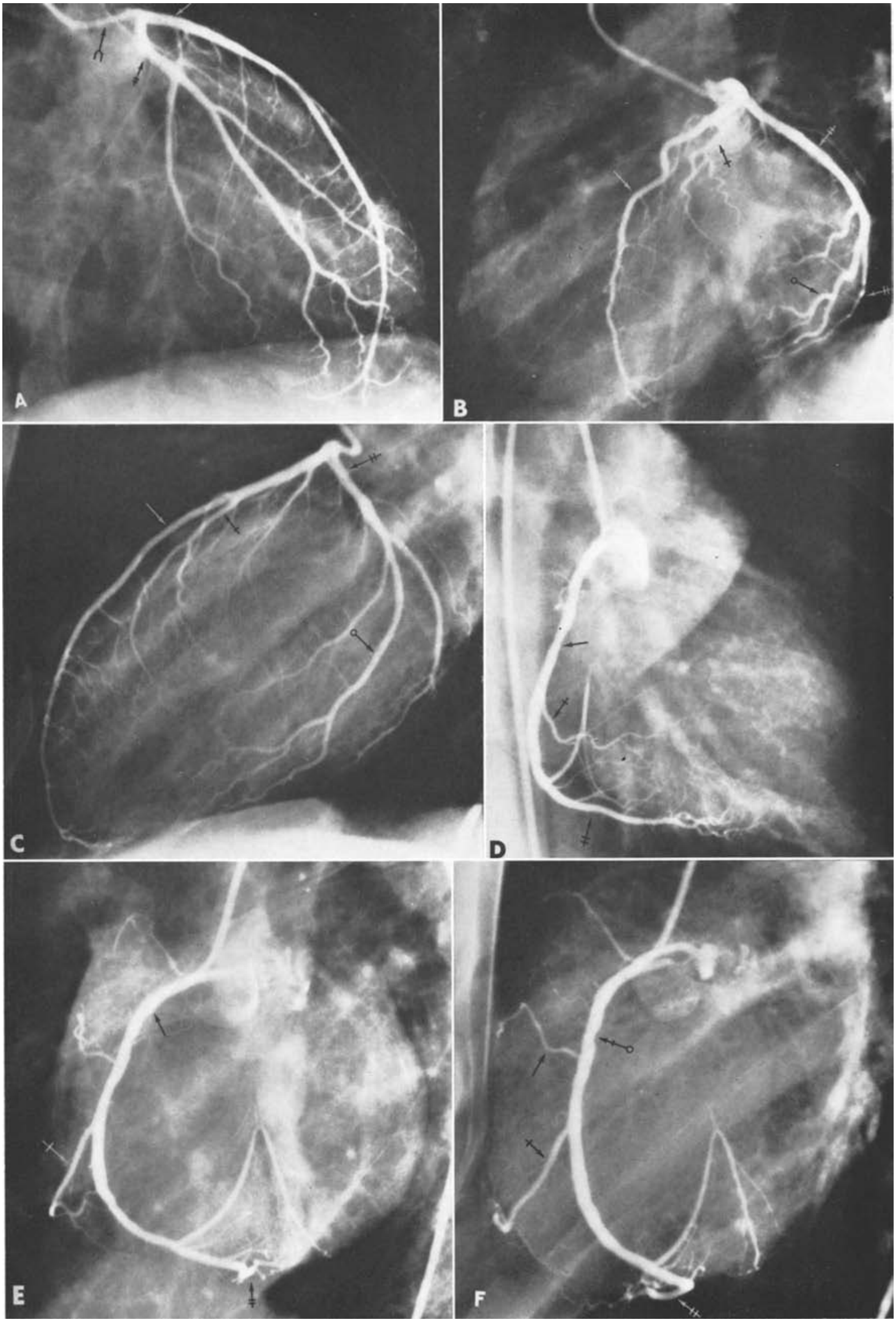


Fig. 6. For legend see opposite page.

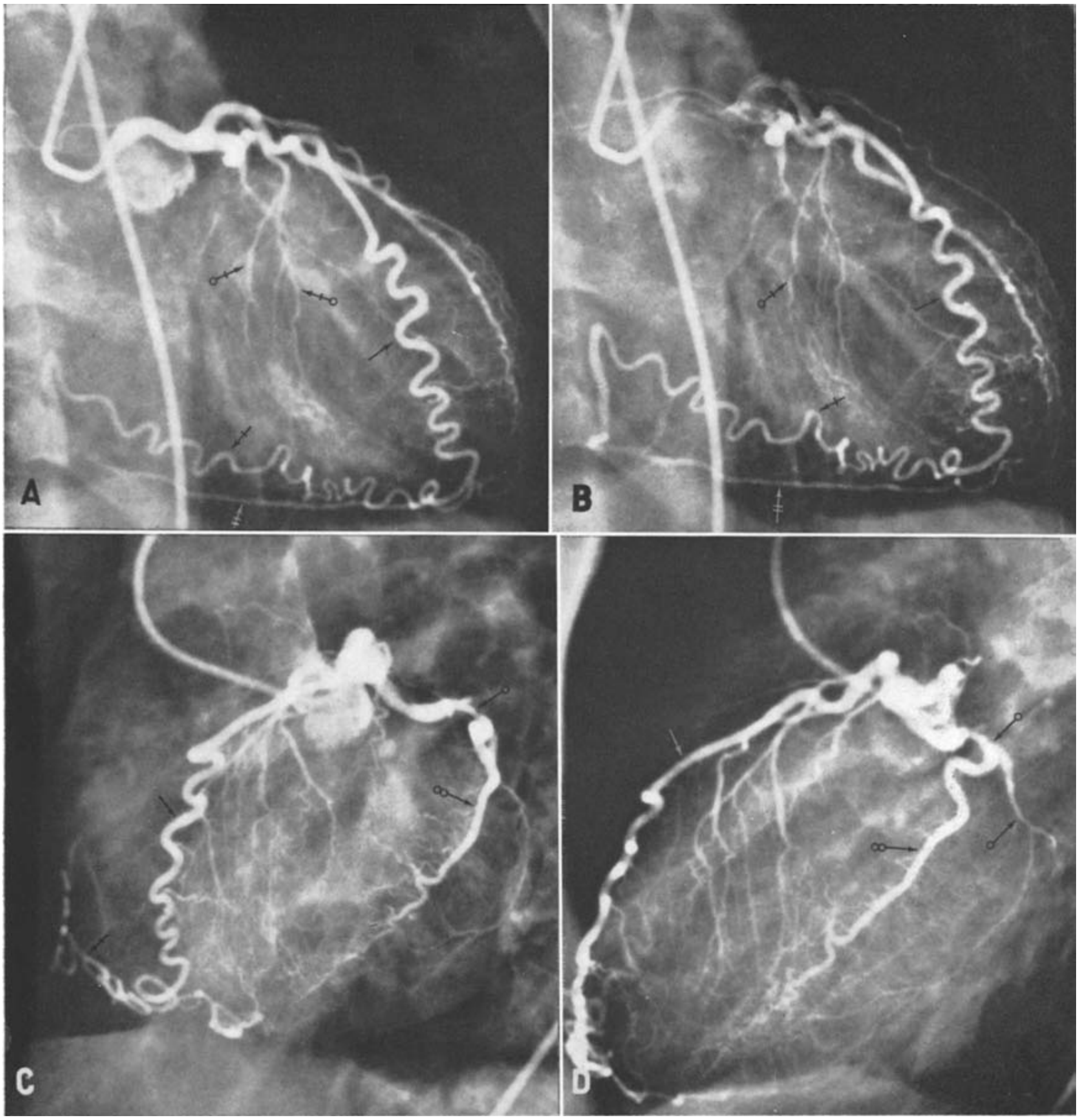


Fig. 7. *Selective Left Coronary Arteriogram:* A. RAO—early filling phase. Tortuous anterior descending branch ↑ . Direct collateral filling of acute marginal ‡ and posterior descending branches ‡ , right coronary artery.
B. RAO—later views. Complete retrograde filling of entire distal right coronary. (Main right coronary is occluded from near its orifice to origin of acute marginal branch.)
C and D. LAO and lateral—large septal vessels contribute to the deficient distal right circulation. Marked narrowing of the circumflex ↕ proximal to its obtuse marginal branch ↕ can be seen on both views. The patient does not appear to have sufficient potential collateral circulation to the distal circumflex system to survive an occlusion of this narrowed vessel.
Septal branches ‡ .

steel wire braid) has been modified. (*a*) The tip was changed from the usual "pencil tip" to a "bullet nose" configuration to minimize the chance of intimal injury. (*b*) The distal 2 cm was thinned to 5.5F (1.8 mm) to avoid coronary wedging. (*c*) The side-holes were eliminated to reduce possibility of clotting in the catheter tip distal to the side-holes and to improve pressure monitoring. This modified catheter, developed with the aid of Robert Stevens,[3] is preshaped into right and left configurations (Fig. 2) over the bending wires similar to those shown in Figure 1.

[3] Research Consultant, Medical-Surgical Equipment, 4207 University Drive, Coral Gables, Fla.

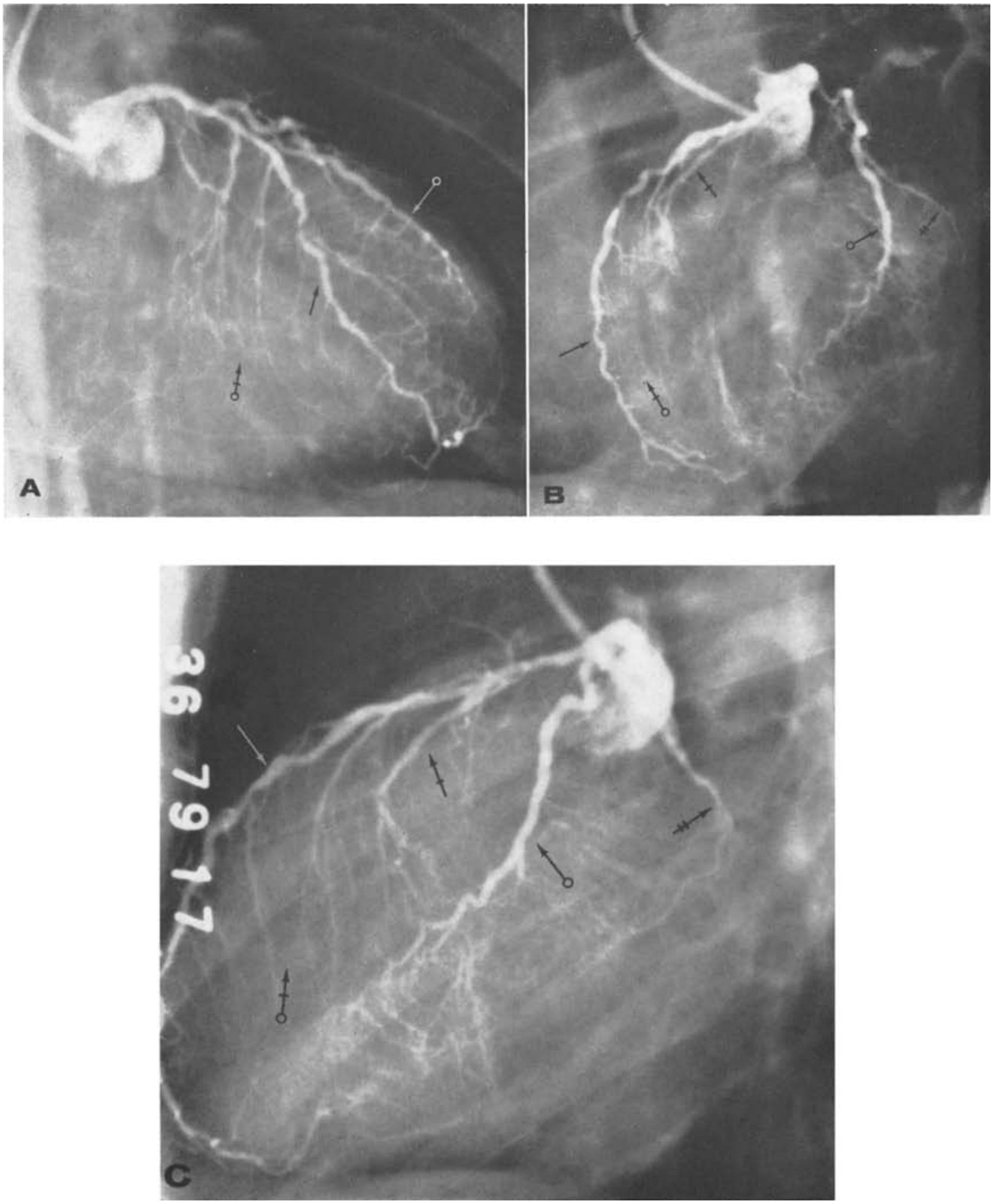
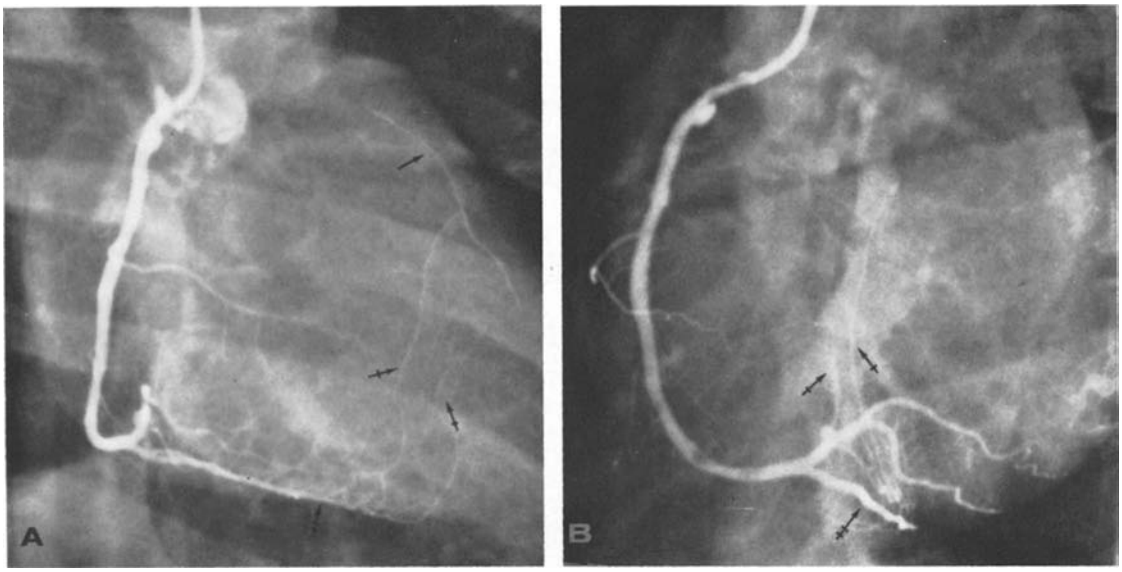


Fig. 8. *Selective Left Coronary Arteriogram:* Diffuse arteriosclerotic narrowing involves the entire left coronary system. Numerous fine vessels enter into local and cross system collateral networks. Anterior descending ↑, diagonal †, obtuse marginal ‡, circumflex ⇞, septal branches ⇟. This patient's right coronary artery is occluded.

Left Coronary: The catheter is introduced percutaneously from the common femoral artery and advanced to the descending thoracic aorta; the leader is then removed, and the catheter cleared and advanced to a relaxed position in the aortic arch (Fig. 3, A). With the patient in a 20° right posterior oblique position to



the table, the catheter tip is advanced down the left wall of the ascending aorta until it drops into the sinus of Valsalva and coronary orifice (Fig. 3, B and C).

Selective hand injections of 6 to 9 cc of Renografin[4] 76 per cent delivered at a rate of about 3 cc/sec. are filmed in the left lateral, left anterior oblique 70°, and right anterior oblique 15° positions (Figs. 4 and 6), both on over-framed ciné film at 60 f/ sec. and by rapid serial filming at 4/sec. for 2 sec. and 1/sec. for 2 sec. To reduce geometric distortion and to avoid misinterpretation of contrast layering, the serial films are taken with a horizontal x-ray beam.

Right Coronary: With the patient again in a 20° right posterior oblique position, the right coronary catheter is advanced to a position a little above the left sinus of Valsalva. The catheter is then rotated *slowly* clockwise (about 180°) until its tip drops into the right coronary orifice (Fig. 5). Injections of 6 to 9 cc of contrast agent are filmed in the lateral, left anterior oblique 70°, and right anterior oblique 20° projections (Figs. 4 and 6).

Myocardial contractility and ventricular aneurysms are evaluated by fluoroscopy in multiple projections and by ventriculography, using a "hook-tail" catheter (1).

[4] Brand of meglumine diatrizoate 76 per cent, from E. R. Squibb and Sons, New York, N. Y.

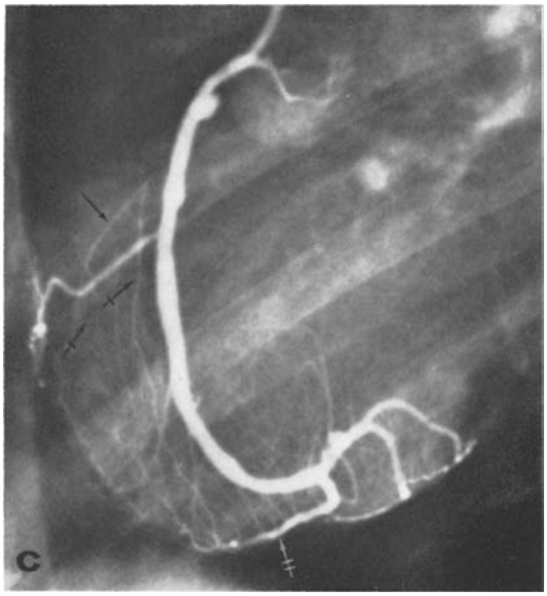


Fig. 9. *Selective Right Coronary Arteriogram:* RAO, LAO, and lateral views. Distal segments of the anterior descending branch ↑ of the left coronary fill *via* septal collateral vessels ‡ from the posterior descending branch ‡ of the right coronary. Small arteriosclerotic aneurysms of the proximal right main coronary are evident.

TECHNICAL COMMENT

This technic is based on the use of catheters preshaped into optimal configurations for simple, rapid, selective coronary catheterization with a minimum of manipulation. Catheters are "over-bent" to obtain the necessary "spring" to hold them in position. To maintain their shape, unnecessary trauma to the catheter tips

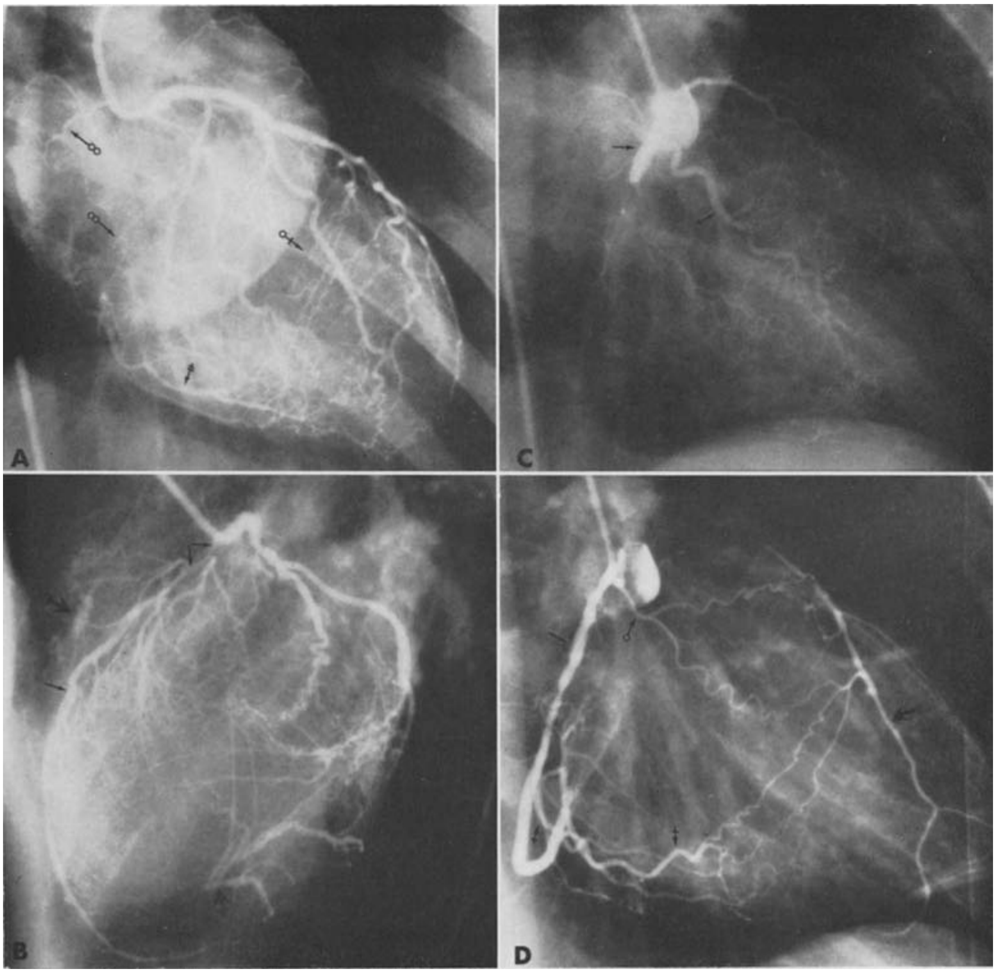


Fig. 10. Views of four different patients—each with collateral circulation to a proximally occluded coronary vessel. Note the anatomical detail in the collateral networks. A. RAO view, left coronary injection. There are numerous septal collateral pathways ‡ to the distal right system *via* its posterior descending branch ‡. Atrial branches also enter into the collateral circulation ‡.

B. Lateral view, left coronary. This film, for the most part, confirms the patient's undocumented history of two myocardial infarctions despite equivocal electrocardiographic changes. The anterior descending branch of the left coronary artery is all but occluded near its origin ↑. The right coronary artery is occluded proximally; a 1-cm fragment of its descending portion is patent ⇑, fed *via* a conus branch from the left. It is occluded from this fragment to the crux where its posterior descending system ⇑ fills from the circumflex coronary. Serial films show the anterior descending system ↑ fills, in part, *via* numerous collateral channels.

C. Right coronary RAO. Right coronary ↑ is occluded at the origin of a right ventricular branch ‡. Collateral vessels cover the surface of the right ventricle to the area of the occluded anterior descending branch of the left coronary artery. This 38-year-old mother of 4 (youngest child is two years of age) has triple vessel disease (her circumflex is also markedly narrowed).

D. Right coronary RAO. The main right coronary artery ↑ is narrowed at multiple points. The acute marginal branch ‡ and conus ‡ branches form a collateral net over the anterior surface of the right ventricle to the anterior descending coronary artery ⇑.

must be avoided. The spring guide inserted through the needle is advanced to the aortic bifurcation before the puncture needle is withdrawn. If an obstruction is encountered, the spring is replaced with a safety J-guide[5] (6). If the J-guide will not negotiate the tortuous iliacs, forget it; the guide and needle may be removed with an arterial needle puncture the only penalty. The only reward for further effort to catheterize that side will be a high complication rate and/or an uncontrollable misshaped catheter.

Following guide passage to the aortic

[5] Safety guides and safety J-guides are products of Cook, Inc., Bloomington, Ind.

bifurcation, a short length (6 in.) of 7F taper-tipped Teflon tubing is inserted into the artery over the guide. This maneuver dilates the soft-tissue tract and arterial puncture hole, making it unnecessary to push or twist the preshaped coronary catheter through the soft tissues and vessel wall. Once it has served its purpose, the Teflon tubing is replaced with the coronary catheter, and the latter is advanced into the aortic arch; prompt removal of the guide then allows the catheter to assume its preset configuration.

The relatively tight bends in the left coronary catheter make guide removal difficult; the pull necessary for removal tends to unravel most guides. The safety guide (3), which contains, in addition to the usual stiffening wire, a small diameter "safety" wire soldered to both ends, will not uncoil when used with these preshaped catheters. A nonstandard 0.038-in. guide is used to insure sufficient stiffness for ease of insertion and removal. A 0.035-in. guide is not satisfactory.

Selective catheterization of the coronary arteries or any other branch of the aorta requires a catheter of suitable configuration and a radius of curvature slightly greater than that required to span the aorta. The length of the left coronary catheter "arm" (the segment between the primary and secondary bend) is only moderately critical. If too short, however, the catheter will double back on itself. If too long, the arm will assume a relatively vertical position in the aorta and rest on the lip of the sinus of Valsalva, thus preventing the tip from reaching the orifice high and deep in the sinus. The relative size of the aorta is estimated on the basis of the patient's size, age, known valvular disease, and the appearance of the aorta in the preliminary films. Three sizes are illustrated in Fig. 3, D–F. The medium size coronary catheter will accommodate 85–90 per cent of the adult patients examined and almost 100 per cent of those without aortic valvular disease or aneurysm.

The shape of the right coronary catheter varies with aortic dimensions. The tip may be shortened or the secondary curve flattened for the small vertical aorta (Fig. 5, E). A catheter with too long a tip or too great a secondary bend will tend to catch in the left sinus, "wind up" as it is rotated, then spin uncontrollably. The angle of the primary bend is reduced to about 70° and/or secondary bend flattened for a dilated aorta (Fig. 5, F). If a catheter becomes deformed as a result of manipulation or if an inappropriate size is selected, the catheter should be removed promptly and be replaced with a suitable new catheter.

Pressures are carefully monitored for signs of damping. If there is any evidence of damping or slowed wash-out on test injections, the catheter is removed and repositioned. An occasional patient will have a small or stenotic coronary orifice into which the catheter will repeatedly wedge. When this occurs, the catheter should be withdrawn, then briefly repositioned when everything is ready for filming; contrast injection must be done quickly, and the catheter removed during the filming.

The selection of contrast material is important to obviate arrhythmias. Meglumine diatrizoate 76 per cent[6] is used exclusively in this laboratory for coronary arteriography, and there has been no instance of an arrhythmia other than transient bradycardia for over 3,000 contrast injections using this and a previous technic. Predictable electrocardiographic changes are noted with each injection (13).

When mitral and/or aortic valvular disease is suspected, the right coronary catheter can, in most cases, be manipulated through the aortic valve and, in many instances with the patient in the left posterior oblique position, advanced through the mitral valve. Pressure contrast agent injections into the left atrium or left ventricle, using the coronary catheter, are not advised, but pressure

[6] Renografin 76 per cent, E. R. Squibb & Sons, New York, N. Y.

records may be obtained. A special percutaneous transfemoral retrograde left arterial catheter will be described in another paper.

Superb photography is essential to record the detail potentially available in any selective study. Special attention should be directed toward elimination of motion blurring, geometric unsharpness, and fogging due to scattered radiation (Fig. 7).

DISCUSSION

Until now, selective coronary catheterization *via* the femoral artery has been frustratingly uncertain and *time-consuming*. The curve of the aortic arch has foiled catheter control in the ascending aorta, making the coronary orifices elusive targets from the near 100-cm distance. Numerous tip-control gadgets and positive-control catheters have been developed, but all lose much of their control on the cardiac side of the aortic arch. The Ducor catheter is no exception, but, when coronary-seeking tip configurations are combined with its positive control feature, *the coronaries may be catheterized with startling consistency and ease.* High-quality selective coronary delineation is the rule (Figs. 8 and 9). Excuses have never been necessary, and there has been no need to resort to a sinus flush for the coronary that could not be entered. Any of the common moldable catheter materials can be used, but they lack the handling ease and control afforded by the positive control catheter.

This technic is an angiographer's approach to selective coronary artery study; the same principles traditional to selective visceral arteriography are employed. Catheters of soft, moldable material are preshaped to conform to the anticipated anatomy. The aortic valves are not used to deform the catheter during the procedure. Once positioned, the catheter will remain in the coronary orifice until it is removed. It may be left in place for multiple contrast injections in the various projections previously described so long as pressure monitoring shows no evidence of damping and test injections quickly wash out. This feature of the technic facilitates direct serial filming.

Ciné photofluorography and direct serial radiography are complementary recording technics—*one never replaces the other*—each should be kept in perspective. Ciné studies vividly portray the dynamics of coronary flow; but anatomical detail is limited by the resolution of the intensifier system. Motion and flow, however, produce an image that fascinates and seems to mesmerize the novice viewer into believing he has seen all. Direct serial radiography depicts an unparalleled wealth of anatomical detail (Figs. 8–10) and portrays dynamic information to the experienced reader. This detail is essential for progress in definitive coronary surgery. *There are no more valid reasons for limiting study of the coronary anatomy to ciné photofluorography than there are for a similar limitation in the study of the cerebral, pancreatic, or renal anatomy.*

Even though selective coronary catheterization is technically simple, coronary arteriography should not be undertaken by the neophyte or without adequate laboratory facilities.

SUMMARY

A new percutaneous transfemoral selective coronary arteriography technic has been devised which can be quickly learned by the resident, fellow, or practicing angiographer. "Coronary-seeking" tip configurations set in a redesigned moldable positive control catheter implement rapid, consistent selective coronary catheterization. Special control equipment or special handles are unnecessary. When properly positioned, the catheters will remain in place for anatomical and dynamic filming in multiple positions. The inconvenience and possible complications of surgical cutdown on a brachial artery or those of percutaneous axillary approach are eliminated.

One hundred patients have been ex-

amined; in each case, both coronary arteries were selectively catheterized and contrast injection was filmed by conventional serial radiography and cinephotofluorography.

ADDENDUM: Since this article was prepared, an additional 200 patients have been studied with results similar to those described in this article. Experience has tended to standardize catheter "sizes." Left coronary catheters are now made up with a 4 cm, 5 cm, and 6 cm distance between the center of the tip and secondary bend (Fig. 1). These have been designated sizes 4, 5, and 6. The No. 4 size is standard. The No. 5 is most useful in the unfolded aortas of older patients and those dilated by long-standing hypertension or medial disease. The No. 6 size is usually needed when there is poststenotic dilatation of the aorta. The normal right, as shown in Figures 1 and 2 (tip length 1.2 cm), is used in all patients except those with severe deformity of the sinuses of Valsalva where the large is preferred. We are now using Teflon-coated safety wire guides. Their use will be described in a subsequent technical note.

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