RADIOLOGIC NOTES IN CARDIOLOGY

Angiographic Appraisal of Distal Vessel Suitability for Aortocoronary Bypass Graft Surgery

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SUMMARY
The accuracy of preoperative coronary arteriography in determining distal vessel operability was evaluated in 166 patients studied arteriographically before and after bypass surgery. Appraisal accuracy correlated closely with the type of distal vessel filling, being highest (97%) in poststenotic vessels with antegrade filling; lower (76%) beyond occlusions with generous retrograde collateral flow; and least (65%) in postocclusion vessels filled by insufficient collaterals. Optimum data collection is favored by the use of high-definition serial roentgenography with extended filming in multiple projections; competent interpretation requires the integrated assessment of interdependent variables, including distal vessel morphology, filling patterns, branch disease, run-off capacity, and myocardial status.

Additional Indexing Words:
Coronary artery disease Myocardial revascularization Coronary arteriography
Aortocoronary venous bypass surgery

In the Evaluation of patients for aortocoronary bypass operations, coronary arteriography and left ventriculography should provide information about the nature and extent of the coronary atherosclerotic lesions, the suitability of the coronary arteries to receive bypass grafts, and the likelihood that sustained improvement in myocardial blood flow will improve cardiac performance. These objectives are not always attained, however, and the reliability and prognostic value of preoperative arteriography have not been fully established. To assess the accuracy of preoperative coronary arteriography in the appraisal of distal vessels, we have correlated preoperative findings with those of direct operative inspection and postoperative arteriography. Our results suggest that meticulous preoperative arteriography, interpreted by methods to be discussed, provides reliable information about distal vessels in most cases. In specific situations, however, preoperative studies can mislead the inexperienced or unwary observer.

Clinical Material and Methods
One hundred and sixty-six patients (143 males and 23 females), had arteriography before and after aortocoronary saphenous vein bypass operations. Ages ranged from 31 to 65 with a mean of 52 years. Operations were performed for chronic disabling angina or acute coronary insufficiency associated with significant obstruction of one or more major coronary arteries. Ninety-five patients had single grafts, 68 had double grafts, and 3 had triple grafts. Operative techniques have been previously reported.

Preoperative studies were carried out one day to three months prior to operation. Follow-up studies were usually carried out after four to six months (range: ten days to two and a half years; mean: five months). Studies were done percutaneously by the femoral or occasionally the axillary approach. Preshaped torque control catheters were used to deliver selective injections into the left ventricle, both coronary arteries, and patent bypass grafts. When grafts were occluded, injections were made into the occluded graft stump, or the aorta adjacent to the anastomotic site. Left
Accurate appraisal of distal vessels. Coronary disease with stenoses of the left anterior descending and occlusion of the right coronary arteries. (A) Preoperative selective left coronary injection. LAD was classified suitable and posterior descending unsuitable for grafting. Surgical finding was in agreement with arteriography and bypass graft to LAD was done. (B) Study six months after surgery. Selective graft injection.

Ventriculograms were filmed cinefluorographically. Selective coronary and bypass arteriograms were filmed in multiple projections by serial direct roentgenography and 35 mm cinefluorography. All arteriograms were evaluated without knowledge of the surgical findings or results. Preoperative arteriograms were analyzed retrospectively in the first 32 patients, and prospectively in the remaining 134. Preoperative arteriograms were studied for the caliber of the principal distal vessels, the extent of distal atherosclerosis, and the size of the peripheral run-off branches. Arterial caliber was determined from the radiologic image, allowing for geometric magnification as based upon real and apparent catheter size. Arteries 1 mm or more in diameter, with little or no distal disease and good peripheral run-off branches were classified as suitable for anastomosis. Smaller or diffusely diseased arteries with minimal peripheral branches were classified as unsuitable for grafting. At operation, grafts were performed if the arterial wall at the anastomotic site was relatively free of atherosclerosis, the internal diameter appeared adequate, and the area supplied by the artery to be grafted consisted of viable myocardium. Postoperative arteriograms were analyzed in terms of graft patency and the state of the coronary arteries proximal and distal to the anastomosis, especially in terms of their caliber and the filling of run-off vessels.

Preoperative findings were considered accurate if they were in agreement with both operative and postoperative findings (fig. 1). Preoperative appraisal was judged inaccurate if a vessel considered unsuitable for grafting was successfully grafted, or if a vessel considered suitable for grafting could not be grafted (fig. 2).

Results

In the 166 patients, 253 arteries were preoperatively judged in need of bypass grafts on the basis of the character and consequences of atherosclerotic obstruction. Of these 253 arteries, the distal vessels were classified as suitable for grafting in 218 and unsuitable in 35. Grafts were inserted into 240 arteries and 13 arteries were found to be unsuitable for grafting at the time of surgery. On follow-up
Inaccurate appraisal of distal vessel. Coronary disease with occlusion of the right coronary and stenosis of the obtuse marginal artery. (A) Preoperative selective left coronary injection. Posterior descending classified unsuitable for grafting because its diameter was less than 1 mm. Obtuse marginal was classified suitable for grafting. At surgery, the posterior descending artery measured 2 mm and double bypass graft to the posterior descending and obtuse marginal arteries was done. (B) Selective graft injection five months after surgery shows well-distended posterior descending artery with 2 mm diameter.

Accuracy of angiographic appraisal of 253 distal coronaries in relation to their filling.

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Figure 4

Underdistended distal vessel. Coronary disease with occlusion of the left anterior descending and right coronary arteries. (A and B) Preoperative, selective left coronary injections in LAO and RAO projections show underdistended distal LAD (arrow) and PD arteries. At surgery both arteries were 2 mm in diameter and double bypass grafts were done. (C) Selective left graft injection 4 months after surgery shows good patency of the graft with interval increase in caliber of both distal vessels. Graft to distal right coronary artery was occluded.
Figure 5
Incomplete distal filling. Coronary disease with occlusion of the left anterior descending artery. (A) Preoperative selective left coronary injection with partial filling of distal LAD. (B) Late phase of the preoperative right coronary injection with partial filling of the distal LAD. At surgery, LAD measured 2.5 mm in diameter and bypass graft was done. (C) Selective graft injection eight months after surgery shows good filling of LAD.

Figure 6
Coronary calcifications. Coronary disease with calcification and multiple obstructions of coronary arteries. (A) Direct roentgenogram shows extensive calcification of the left anterior descending, some of its branches, circumflex and right coronary arteries (arrows). (B) Selective left coronary injection shows occlusion of LAD, circumflex, obtuse marginal and right coronary arteries. At surgery, graft was performed into the posterior descending artery. LAD was unsuitable for grafting.
(146 of 150). In postocclusion vessels filled by collaterals from both coronary systems (ipsilateral and contralateral), the accuracy was 76% (43 of 57). In postocclusion vessels poorly filled by collaterals from only one coronary system (ipsilateral or contralateral), accuracy was only 65% (30 of 46).

There were four principal causes of inaccurate appraisal (table 1).
1) In 24 arteries distal to a severe stenosis or occlusion, preoperative arteriography showed a caliber considerably less than the actual maximum. That this was due to underdistention was evident on postoperative angiograms, which revealed a considerably larger caliber associated with direct filling via a patent graft (fig. 4).
2) In six occluded arteries filled distally through bilateral collaterals, we did not correctly assess the extent of peripheral atherosclerosis (fig. 5). These distal vessels encountered early in our experience were poorly seen on individual angiograms, due to nonopaque contralateral washout. We did not evaluate them, as we would now, by integrating the filling from both collateral systems.
3 and 4) Early in our experience we also underestimated the adequacy of run-off vessels in two patients and failed to diagnose diffuse calcifications of peripheral coronary arteries in two other patients.

Discussion
Accurate appraisal of coronary arteries distal to stenoses or obstructions is an important contribution of coronary arteriography to the selection of patients for bypass grafting. Recently published studies indicate that graft patency correlates closely with the caliber and run-off capacity of the grafted artery, and to a lesser extent with its freedom from atherosclerosis.4-7 Grafts anastomosed to large arteries with extensive peripheral vascular beds free of significant disease show 91 to 96% early and 72% late patency.4-6 On the other hand, 70% of grafts

Figure 7
Coronary dynamics. Coronary disease with multiple stenoses and akinetic lower anterior heart wall. Selective left coronary injection in diastole and systole. (A) Diastole shows elongated and straightened coronary arteries. (B) Systole shows shortening and tortuosity of the circumflex artery branches and immobility and rigidity of the lower left anterior descending artery.
anastomosed to small or diseased arteries with only limited run-off occlude within 20 weeks, and virtually 100% occlude within one year.

Several technical and interpretative factors influence the accuracy of distal coronary appraisal.

1) Good radiographic technique is essential. Maximum information can be obtained only through the use of both cinefluorography and direct serial roentgenography. Cinefluorography provides functional information, while direct roentgenography provides the excellent anatomical detail necessary for optimal small vessel evaluation.

2) The use of extended filming and multiple projections are important technical factors. Vessels beyond an occlusion, supplied by collaterals, often fill slowly. To insure their visualization, a prolonged injection of contrast agent should be used, and film timing should be extended over a period of five seconds instead of the usual three seconds. In slowly filled vessels, gravity-dependent layering of contrast agent can cause incomplete filling. Multiple projections assure correct evaluation.

3) Coronary calcifications should be sought carefully. These are most readily detected fluoroscopically and can be recorded by cinefluorography; they are easily missed on direct roentgenograms. While centrally situated local coronary calcifications are usually of little surgical importance, diffuse distal vessel calcifications often make bypass grafting impossible (fig. 6).

4) Valuable information can also be obtained through an appraisal of coronary dynamics. This is best appreciated by cinefluorography, but serial roentgenograms are also useful. The coronary arteries are normally straighter in diastole and more tortuous in systole. Localized weak, absent, or paradoxical ventricular contraction may be apparent as areas of diminished tortuosity in systole or abnormal coronary displacement (fig. 7).

5) Distal vessel caliber must be evaluated in relation to the type of filling. Poststenotic vessels

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**Figure 8**

Good distal vessel distention. Coronary disease with stenosis of the right coronary artery. (A) Preoperative selective right coronary injection shows distended distal vessels. (B) Selective right graft injection 6 months after surgery shows graft patency and continued distention of distal vessels.
with antegrade filling are usually adequately distended, well visualized, and easily measured with accuracy (fig. 8). The main vessel and its branches distal to stenoses are rarely (3% in this series) incompletely distended. Underdistention is more often a limiting factor (35% in this series) in postocclusion vessels filled by minor collaterals from only one (ipsilateral or contralateral) coronary system. Preoperative angiographic measurements of these vessels do not show the potential caliber achievable by successful revascularization (fig. 9). In this situation, appraisal of the distal vessel must rely mainly on its general appearance and the extent of its run-off system.

The vessel distal to a complete occlusion and well supplied by collaterals from both coronary systems is usually well distended, but often incompletely visualized by a selective injection into either (right or left) coronary system (fig. 10). A collective evaluation of both angiograms can overcome this problem. If distal continuity of a given vessel is shown by collective evaluation of both injections, the vessel is open; if only short segments fill, our experience has shown that it is not patent and grafting is not possible (fig. 11).

6) Minor distal vessel atherosclerosis does not preclude surgery or substantially influence graft patency. The more advanced the disease, however, the poorer the prognosis for graft patency and clinical improvement. Coronary angiography shows

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**Figure 9**

Incomplete distal vessel distention. Coronary disease with occlusion of the right coronary artery. (A) Preoperative right coronary injection shows underdistention of the distal right with 1.5 mm diameter. (B) Selective graft injection two and one half years after surgery shows graft patency and 2.5 mm diameter of distal right coronary artery.
Incomplete distal vessel filling from contralateral washout. Coronary artery disease with occlusion of the right coronary and stenosis of the left anterior descending arteries. (A) Preoperative selective right coronary injection shows incomplete filling of the distal right coronary artery. (B) Preoperative selective left coronary injection shows incomplete filling of the distal right coronary artery and its acute marginal branch (arrows). (C) Selective graft injection 4 months after surgery shows good filling of the grafted acute marginal and distal right coronaries.
the extent and distribution of distal atherosclerosis, and in so doing, it permits the selection of the best available site for the anastomosis beyond the last significant lesion.

7) Peripheral run-off capacity is an important determinant of distal vessel operability.4-6 A large, uninvolved vascular bed perfusing considerable myocardium favors continuing patency by insuring sufficient flow through the graft to prevent its thrombosis. If the run-off bed is poor and its capacity low, the resulting sluggish flow through the graft predisposes to thrombosis7 (fig. 12). This can occur even if the grafted artery is of good caliber at the site of anastomosis. In stenotic vessels, the peripheral run-off branches are usually well visualized and easily evaluated. In complete occlusion, because of faulty collateral filling of the peripheral vessels, their potential caliber and capacity are likely to exceed what is directly evident on preoperative studies.

8) While the arteriographic appraisal of distal vessels is important, it is only a part of patient evaluation for bypass graft surgery. Distal vessel findings must be considered in the context of regional myocardial function and overall left ventricular contractility as seen on ventriculography.

Figure 11

Minimal segmental distal filling. Coronary disease with occlusion of the left anterior descending and right coronary arteries. Preoperative study. (A) Selective left coronary injection with good visualization of small, nondistended distal right and posterior descending arteries. There are only minimal traces of LAD (arrows). (B) Selective right coronary injection shows minimal filling of the interrupted LAD (arrows). At surgery, LAD was found completely obstructed and not graftable. Graft was inserted into PD and was occluded at follow-up study 3 months post-surgery.

Conclusion

Coronary arteriography is a reliable method for appraising the suitability of the distal coronary vessels for bypass graft surgery. Accuracy depends on the techniques of examination and interpretation. High definition serial roentgenography plus cinecoronary arteriography offer the best available radiologic approach, and should be used in the routine search for calcification, the analysis of coronary dynamics, and the integrated assessment of distal vessel caliber and disease, filling pattern, run-off capacity, and myocardial status. If the foregoing factors are fully understood and exploited, diagnostic accuracy should exceed the 86% achieved in this series.

References

Figure 12
Poor run-off capacity and graft failure. Coronary disease with high stenosis of the left anterior descending artery and multiple small vessel occlusions. (A) Preoperative selective left coronary injection shows small distal LAD with poor run-off vessels. At surgery, LAD appeared adequate to anastomosis and bypass graft surgery was done. (B) Selective injection into the occluded graft stump 3 months after surgery.


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