VOLUME THREE | NUMBER THREE

Cardiac Surgery 2

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F. A. DAVIS COMPANY, PHILADELPHIA

 Manufactured in the United States of America. Library of Congress Catalog Card Number 74-167951.
ISBN 0-8036-4568-6

Cardiovascular Clinics Series:

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Editor's Commentary

This issue and the last explore in great detail virtually all of the important clinical aspects of cardiac surgery, i.e., indications for surgery, technical considerations, pre- and postoperative care, anesthesia, cardiopulmonary bypass, assisted circulation, prosthetic and biologic valves, pacemakers, and cardiac transplantation. Does the clinician need to know all of these details? Or is it enough to recognize the clinical disorder and make the necessary referrals? In my own view, the referring clinician should have sufficiently broad comprehension to recognize the underlying problem, to discern the potential therapeutic approaches, and to assess the totality of the surgery including followup considerations. In fact, the referring physician has a unique role, indeed a central one, in deciding whether the patient might be a surgical candidate, often in helping the patient to decide whether to undertake surgery and, finally, in managing the patient after surgery. In order to fulfill his role, the clinician requires a broad base of information. Doctor Harken and I are hopeful that these two issues will help to make the clinician's task a little easier.

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Contents

Myocardial Revascularization by Direct and Indirect Methods

Donald B. Effler, M.D.

The current era of surgical treatment for ischemic heart disease began with the introduction in 1958 of Sones's technique for selective coronary arteriography.[1] Utilization of this invaluable diagnostic tool has contributed immensely to our understanding of the most common form of acquired heart disease. Selective coronary arteriography does more than establish either the presence or the absence of occlusive coronary artery disease. For the first time we have the means to define the precise needs of the patient who suffers from ischemic heart disease. Fringe benefits of coronary arteriography are numerous. The anatomy of the coronary circulation can be studied by a kinetic form that replaces the tedious postmortem dissection used since the time of Vesalius. Coronary arteriography is the *sine qua non* of case selection for patients who will require revascularization surgery and, as important, offers the logical method of appraising the results among surviving patients. There is little doubt today that revascularization surgery begins and ends with selective coronary arteriography (Fig. 1).

The need for effective surgical treatment in the management of ischemic heart disease is all too apparent. In the United States alone an estimated 600,000 patients die each year from myocardial infarction or its complications; it is estimated that between 15 and 18 million patients are symptomatic because of coronary artery disease. Time-honored medical therapy does little to change the clinical course of the patient who becomes increasingly symptomatic as result of coronary atherosclerosis; this is particularly true for the patient who has already survived a myocardial infarction. The rationale of surgical treatment for ischemic heart disease is to provide sufficient blood from an extracardiac source to overcome existing myocardial perfusion deficit. The introduction of selective coronary arteriography combined with adjunctive techniques of ventriculography and mammary arteriography have shown that ischemic myocardium can be effectively revascularized. If the critical observer will brush aside the skepticism and the emotional factors that obscure current thinking toward revascularization surgery he will see several inescapable facts. Myocardial revascularization is a reality—it is here and will remain so. The primary questions that we must answer are: What is its full potential and what effects will it have upon the factors of rehabilitation and longevity among patient sufferers?

SURGICAL TREATMENT

In 1961 Sones[2] demonstrated the validity of Vineberg's hypothesis in three patients who had survived five or more years after internal mammary artery implantation. These observations introduced the current era of revascularization surgery, as the first efforts utilized implantation procedures. It is ironic that modern revascularization surgery begins by the exhumation of a surgical approach suggested in 1946. Increasing familiarity with the management of postoperative coronary patients prompted consideration of direct operations upon segmental occlusions of major coronary arteries. Initially, endarterectomy techniques were attempted but these soon gave way to patch-graft reconstruction of the critically obstructed vessels.[3,4] More than any single

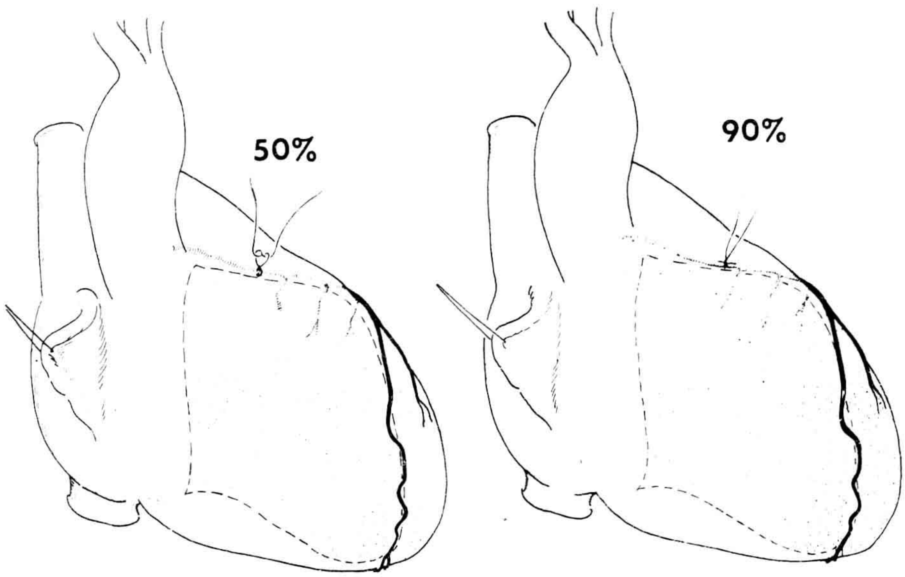

Figure 1. The problem that confronts the coronary patient is illustrated in simplest form. The artist has copied the commonest pattern of the left anterior descending coronary artery as it is seen by cine coronary angiography. This particular vessel is selected as it is the single vessel most commonly obstructed by coronary atherosclerosis.

Left, Placement of a ligature around the proximal anterior descending branch of the left coronary artery, and immediately proximal to the first septal perforators that supply the anterior aspect of the interventricular septum. If the ligature occludes the vessel by 50 per cent of normal luminal caliber, there is no major disturbance in coronary flow.

Right, Occlusion of the anterior descending coronary artery by 90 per cent of its normal luminal caliber creates a potentially catastrophic situation. The myocardium perfused by the anterior descending distribution is now subjected to anaerobic metabolism and if the vessel is totally occluded by superimposed spasm, the subject is in imminent danger of sudden death or massive myocardial infarction.

To evaluate the needs of the individual patient one must rely upon selective coronary arteriography to determine both the exact location of a significant occlusion and the degree of obstruction. From a practical standpoint, 50 per cent occlusion of a major coronary artery does not constitute an indication for revascularization surgery. On the other hand, 90 per cent occlusion of a proximal main coronary artery constitutes an urgent consideration for myocardial revascularization.

factor, the introduction of the venous bypass graft techniques in May, 1947 stimulated widespread interest and participation in revascularization surgery.

At this writing there is escalating enthusiasm for revascularization by the bypass graft techniques. It is unfortunate that this trend has been associated with a diminishing interest in the mammary artery implantation procedures. The fact that both the direct and the indirect methods of myocardial revascularization have their proper places is being overlooked by many cardiac surgeons who are in a position to know better. The purpose of this report is to point out the salient advantages of each method of myocardial revascularization and, hopefully, clear the light smog of emotionalism that is associated with both approaches.

Direct Bypass Procedures

The obvious rationale of the bypass graft technique is to reestablish flow in a proximally occluded main coronary artery. It requires no great intelligence to see how application of a simple plumbing principle may reestablish an effective flow of arterial blood when the run-off bed is intact and the involved myocardium is unscarred (Figs. 2 and 3). The techniques of bypass graft surgery are well standardized after more than four years of accelerating clinical application. The majority of these procedures utilize a simplified form of extracorporeal circulation. Adjunctive procedures include electrically induced ventricular fibrillation, anoxic cardiac arrest and small vessel suture techniques that are easily mastered.

The benefits of successful bypass surgery on patients who are carefully selected for such procedures are obvious. This direct approach offers "instant revascularization" and by so doing affords immediate protection to the jeopardized area of myocardial perfusion deficit. In effect the arterial distribu-

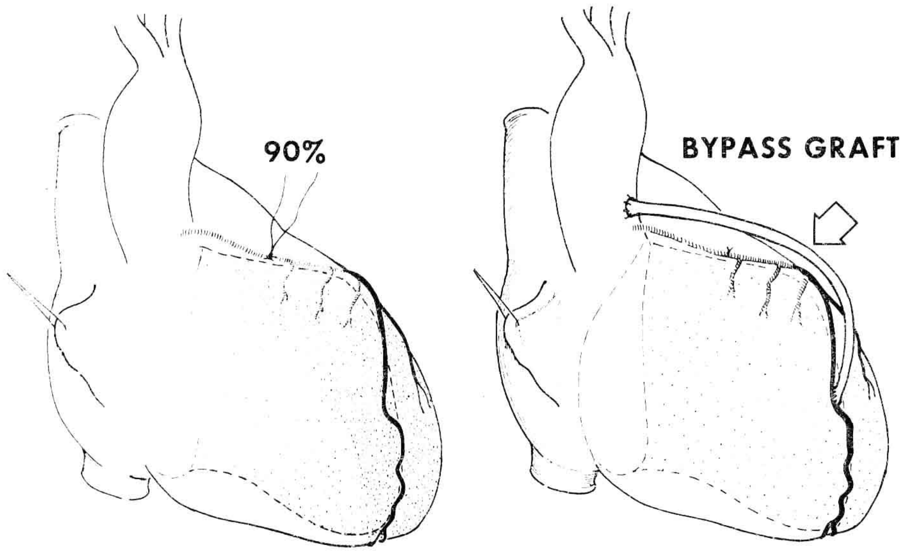

Figure 2. This figure illustrates the direct approach to revascularization surgery by the bypass venous graft technique. This approach to the surgical treatment of ischemic heart disease was introduced to the Cleveland Clinic experience by Doctor René G. Favaloro in 1967.

Left, The indication for direct revascularization surgery. The open myocardium is in imminent danger of infarction by the pathologic ligature that is placed immediately proximal to the first septal perforating branch.

Right, The solution to the problem is a long venous bypass graft from the aortic root to the distal midportion of the left anterior descending artery. Ideally, the distal anastomosis is so constructed that flow may proceed in both an antegrade and retrograde direction within the left anterior descending artery.

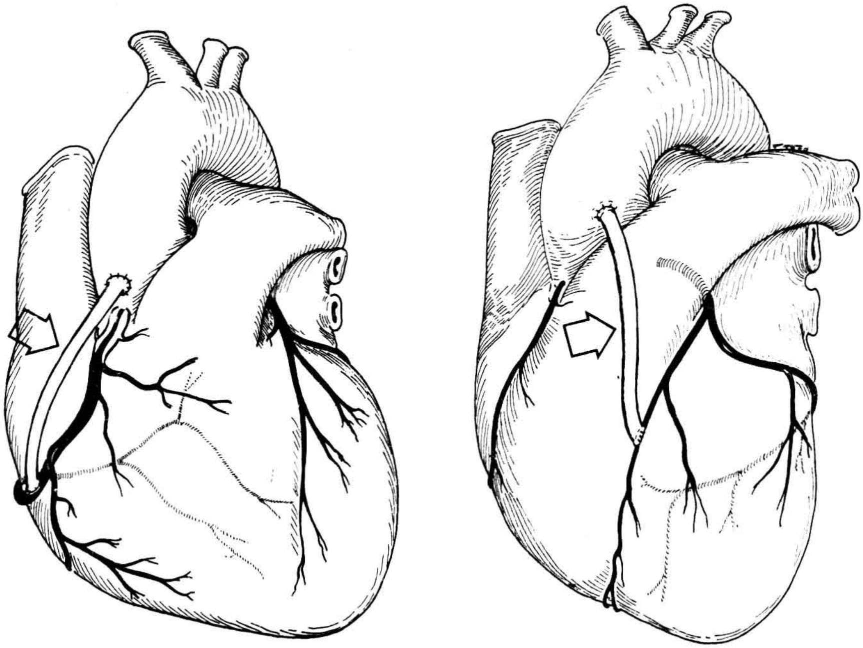

Figure 3. Left, The bypass graft as applied to the dominant right coronary artery. Here the artist has shown the venous bypass graft entering the midportion of the dominant vessel; in actual practice the bypass graft is usually brought down to the diaphragmatic aspect of the left ventricle, beyond the lowest marginal branch.
Right, The venous bypass graft to the anterior descending branch of the left coronary artery. The distal anastomosis is usually made in the mid third of the left anterior descending artery well below the major diagonal branch.

tion area that was jeopardized by a proximal obstruction is freed from the threat of intolerable anaerobic metabolism which could produce either sudden death or the crippl ng effects of myocardial infarction. The immediate protection afforded by the venous bypass grafts makes this form of surgery valuable in both the *chronic* and the *acute* phases of threatened myocardial infarction. The potential for prompt rehabilitation of the patient who suffers from ischemic heart disease is obvious and this has converted many cardiologists into supporters of at least one form of revascularization surgery.

Enthusiasm for any form of surgery should never blind the critical observer to attendant disadvantages. The concept of the venous bypass graft is not original with cardiac surgeons; it has been used in peripheral vascular surgery for many years. The literature is sprinkled with reports which describe undesirable changes in the arterialized vein graft when applied to the lower extremities; these include thrombosis, calcification, and aneurysm formation. In the Cleveland Clinic graft thrombosis has occurred in approximately 10 per cent of surviving patients; this undesirable complication is most likely to occur within the first months after operation. Follow-up studies, now going into the fifth year, have failed to demonstrate either calcification of the vein graft or recognizable aneurysmal changes. Biopsies of two patent vein grafts, taken 18 months or longer after operation, show minimal lipid deposition as the only recognizable change. The peculiar pathologic processes recently reported by Johnson and associates[5] have not been recognized in the Cleveland Clinic series. Another factor that has concerned the cardiac surgeon is the obvious luminal discrepancy between the larger vein graft and the smaller coronary artery. It was anticipated that this luminal discrepancy, which may exist in a ratio greater than 10:1, might produce an undesired turbulence that would limit the period of initial graft success. At this time degeneration of the arterialized vein graft and luminal discrepancy seem to be factors more hypothetical than real.

With increasing clinical experience our concern is less for the vein graft itself than for the involved coronary artery. The atherosclerotic process that produces occlusive disease may react in unpredictable fashion. In most patients critical occlusions occur in the proximal coronary arteries, while the distal vessels may be remarkably free of pathologic change. Under this condition the bypass graft approach may be most attractive. In some patients the atherosclerotic process is diffuse and moves relentlessly to involve the entire subepicardial distribution of the coronary arterial circulation. Yet, we have serial arteriograms that demonstrate critical occlusive lesions that, for no apparent reason, remain stable over a period of years; the threatened total occlusion, for reasons unknown, simply does not materialize. The unpredictable nature of coronary artery disease makes each patient an individual unto himself. But the fact remains that the atherosclerotic process tends to be progressive and functioning vein grafts can be compromised by progression of the atherosclerotic process. It is unrealistic to believe that an arterialized vein graft can accommodate itself to peripheral extension of occlusive coronary artery disease. Therefore, the thoughtful surgeon concerns himself with both the vein graft itself and the coronary artery that it serves. Initial success that attends a venous bypass graft may be later negated by uncontrollable facets of the underlying disease process and the tissue structures involved.

Mammary Artery Implantation

Vineberg's revascularization concept by mammary artery implantation was perhaps the most exotic of all the procedures attempted in an earlier era of revascularization surgery (Fig. 4). Reports of his laboratory research were made in 1946;[6] clinical application began in the early 1950s.[7] The absence of coronary arteriography virtually eliminated any chance for widespread acceptance of the Vineberg approach.

The rationale of revascularization by mammary implantation requires fundamental knowledge of collateral response in areas of myocardial perfusion demand. Many detractors of Vineberg's work have failed to understand how an implanted systemic artery can effectively support a diminishing coronary circulation—lack of fundamental knowledge is always helpful in the development of a negative attitude.

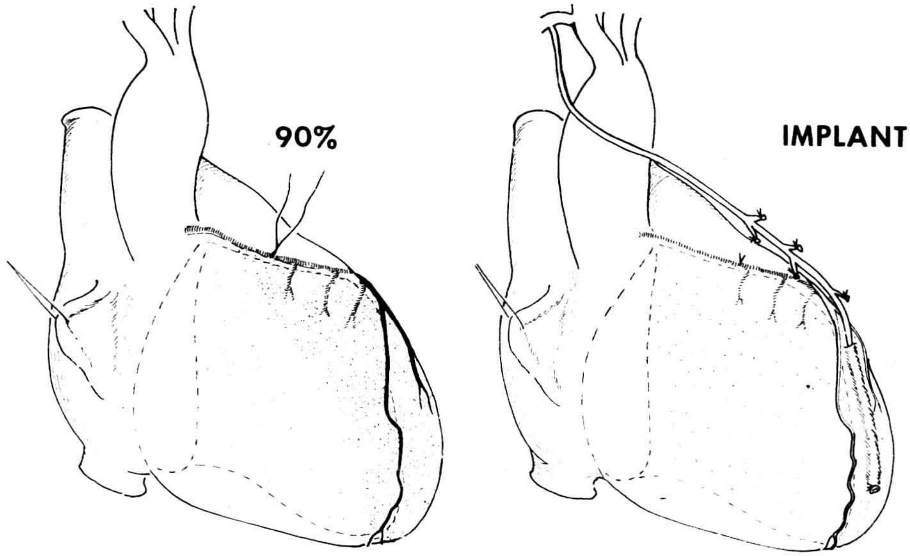

Figure 4. Left, The problem of myocardial ischemia is again illustrated in simplest form. Whereas the problem is identical to the situations illustrated in Figures 1 and 2, we will now suppose that the coronary artery is diffusely involved but unsuitable for a venous bypass graft.

Right, The bypass principle offered by Vineberg's internal mammary implant technique. Here the right internal mammary artery has been implanted in a relatively long tunnel on the anterior wall of the left ventricle where it runs parallel to the anterior descending branch of the left coronary artery. This constitutes indirect revascularization surgery and requires a period of months before true protection is afforded to the myocardium that is compromised by the occlusive disease.

Ventricular myocardium resembles skeletal muscle only in its basic color. During life, heart muscle is never in a resting phase and it requires adequate arterial perfusion to maintain normal aerobic metabolism. The major arterial tributaries of the coronary circulation are on the surface of the heart; only the nutrient branches dip into the myocardium itself. Coronary atherosclerosis is a superficial disease in that it involves only the subepicardial arteries. The usual pattern of artery to vein circulation exists in the myocardium, but on the venous side of the circulation there are additional structures that make heart muscle unique. The sinusoids demonstrated by Wearn[8] give heart muscle a spongelike quality and provide an almost unlimited runoff for any physiologic fluid. As a result, hematoma within myocardium is virtually unknown, regardless of the mechanism of insult. In his early experimental work, Vineberg took advantage of this peculiar property when he implanted the internal mammary arteries of experimental animals; the bleeding side-branches did not produce hematoma, as the saturated blood was carried off in the venous circulation. When mammary artery implantation was accomplished in an area of progressive functional demand for blood, arteriolar proliferation occurred from the side branches of the mammary artery and it was concluded that an extracardiac