Extended Treatment of Severe Coronary Artery Disease:

A Total Surgical Approach

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The human heart has amazing reserve. No one has yet been able to accurately define how much reserve it has. When has effective function been hopelessly lost? Many have tried to answer this, for the literature is full of contraindications for coronary surgery. For example, left or right heart failure, massive aneurysms, dyskinetic or akinetic myocardium, or, left main coronary disease have all been listed as surgical contraindications.[1, 3, 4] We have not accepted these factors, and instead have worked on the simple hypothesis that the ischemic human heart must inevitably work better if new blood is provided and all large areas of solid scar, or aneurysms, are removed. Our emphasis has been on the extensive revascularization and reconstruction of the end stage heart, rather than on the replacement of a sick heart with one soon likely to become even sicker.

Conventional surgical procedures are believed to be inadequate for the end stage patient. A term commonly used in discussion of coronary surgery—"careful selection of patient"—makes any evaluation of results meaningless since those most in need of help are denied surgery. During the past 27 months, over 97 per cent of all patients presenting with significant disease have been accepted for surgery. In the past 11 months, no patient has been refused on the basis of the extent of the coronary disease. A total of 301 patients have undergone surgery since our initial efforts in February, 1967. Seventy-one per cent have had one to six previous infarcts, 53 per cent have had over 75 per cent stenosis in all three arteries, 33 per cent have had mild to severe degrees of left ventricular failure with end-diastolic pressures as high as 53 mm. Hg, and 12 per cent of patients have had ventricular aneurysms resected. The total mortality has been 12 per cent.

To achieve maximum revascularization and improve ventricular function, two basic technics have been developed and a third expanded.

(1) An extended system of indirect revascularization is used in which four to nine separate arterial implants are made into all areas of the left ventricle.

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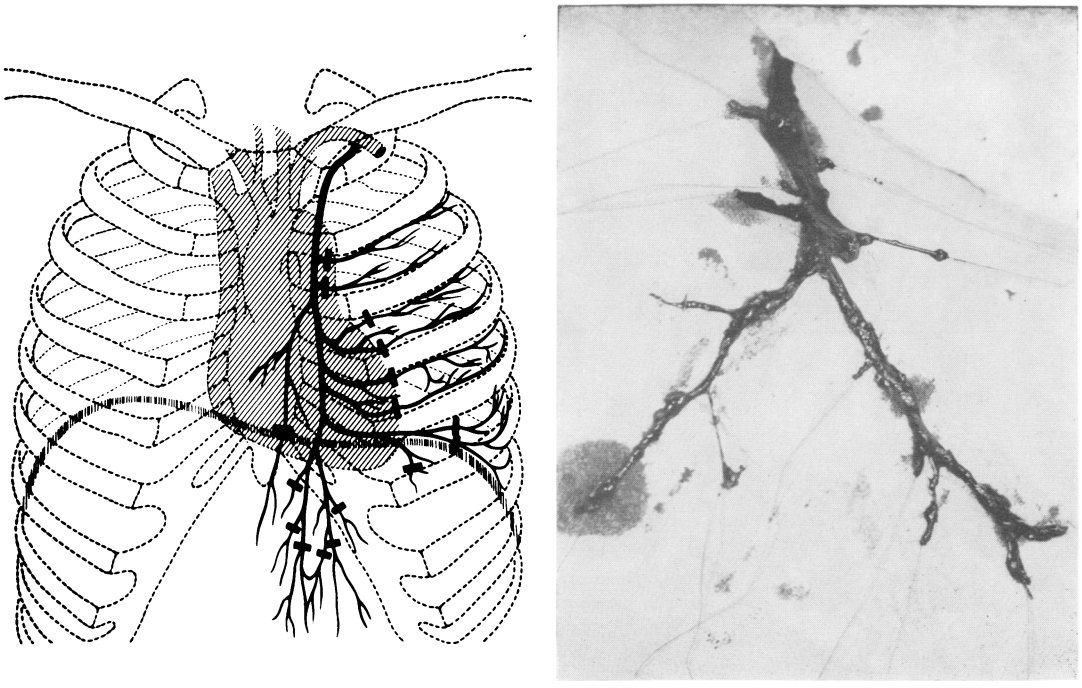

FIG. 1. The pedicle used for the multiple implant procedure is obtained through a sternal splitting incision. Intercostal, mediastinal and superior epigastric branches are left attached to the main mammary artery. As the pedicle is placed over the surface of the heart, the side branches are individually implanted beneath all major coronary arteries.

(2) To immediately increase coronary flow and improve ventricular function, a system of fine vessel anastomosis has been perfected in which free vein grafts can successfully be sutured to any coronary artery 1½ to 2 mm. or larger. Single or double vein grafts are inserted into any one or combination of arteries.

(3) All ventricular aneurysms are resected, usually in combination with one or both revascularization procedures.

The simultaneous application of two or all three of these technics in over 90 per cent of patients has allowed us to accept all so-called end stage patients in the past 11 months. The day is gone when coronary surgery should be thought of in terms of one or two arterial implants. We have not done a single or double implant in over 12 months and consider this an outmoded procedure. The technics used offer immediate clinical and physiologic improvement

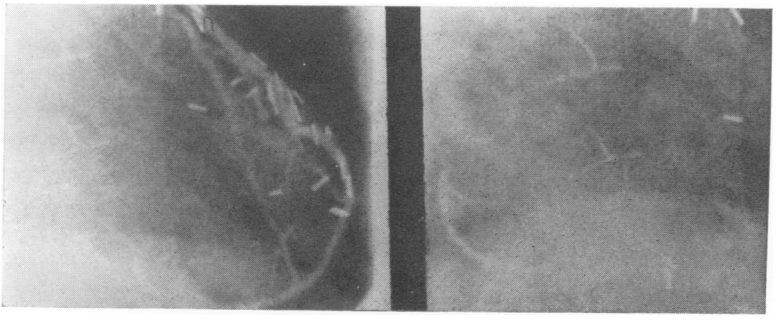

FIG. 2. A typical follow-up angiogram 6 months after multiple arterial implants. The hypertrophied mammary artery courses over the surface of the heart as the side branches fill the anterior descending and the whole distal right coronary.

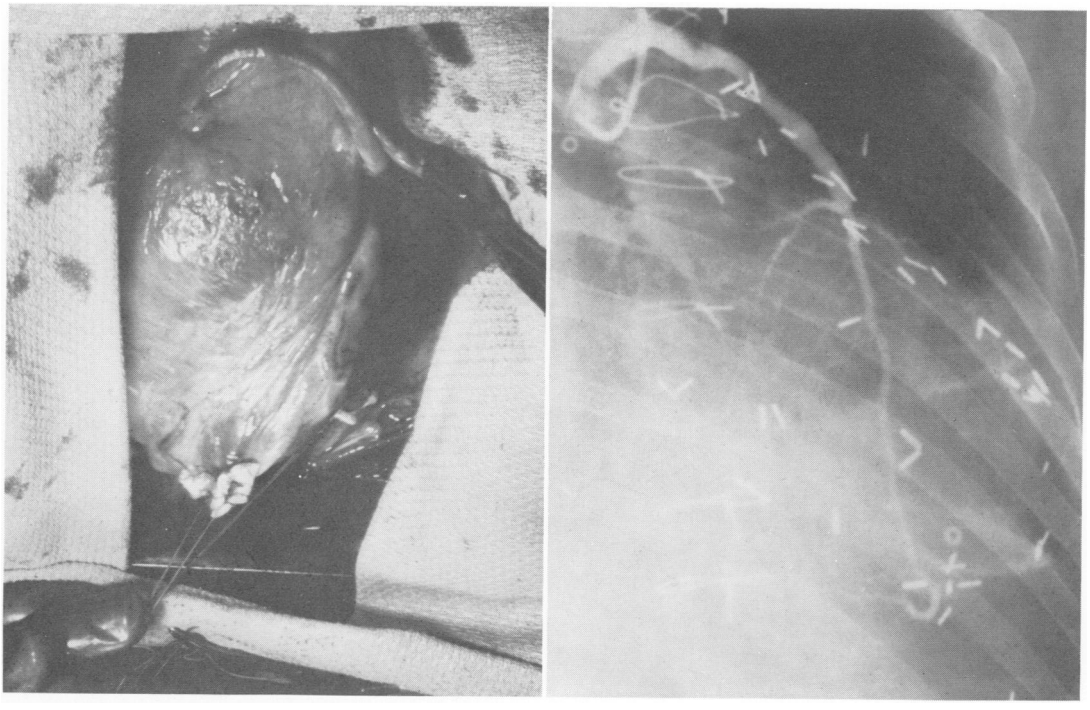

FIG. 3. Left coronary vein grafts arch from aorta, over the pulmonary artery and into either the circumflex artery (operative photo) or into the anterior descending artery (angiogram).

to nearly all coronary patients, and in end stage patients, at a risk well below that of transplantation. The following examples illustrate these operative procedures.

Indirect revascularization is achieved with a pedicle system centered about the left mammary artery. This is mobilized leaving the major side branches (intercos-

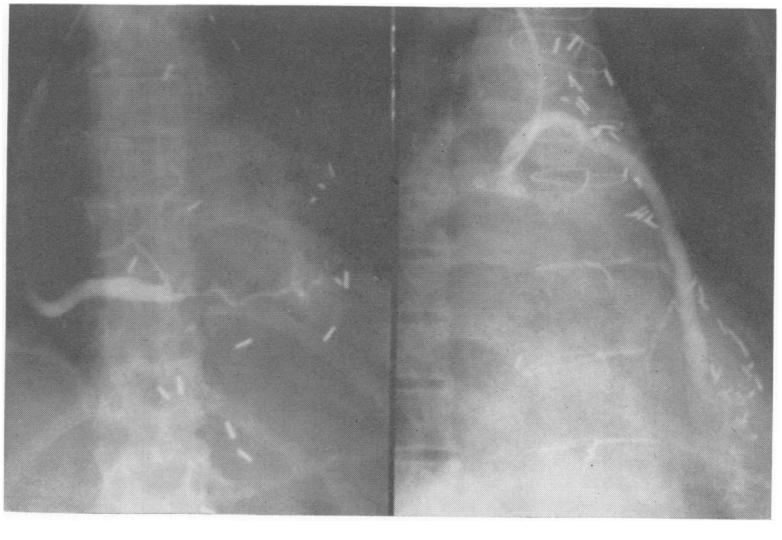

FIG. 4. Vein grafts should not be limited to large arteries. In the first case (left) a graft was sutured to a posterior marginal artery when the posterior descending was diffusely diseased. The second angiogram (right) illustrates a graft connected to the distal one third of anterior descending artery.

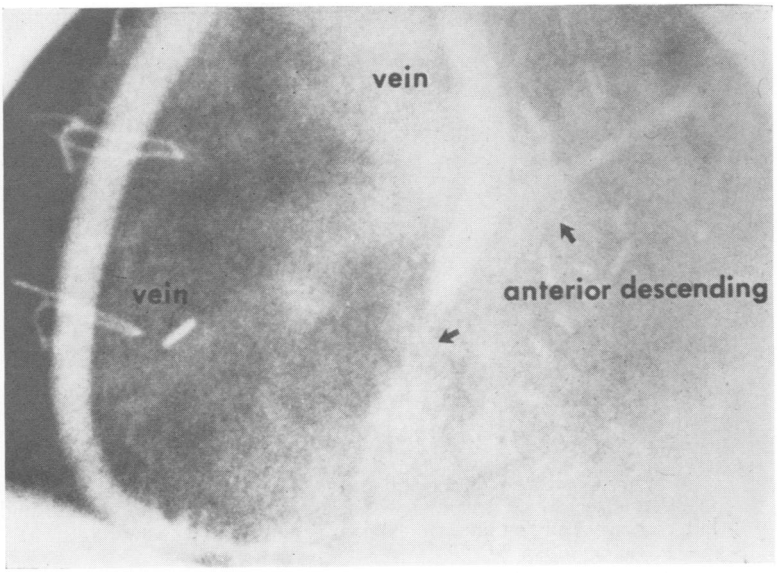

FIG. 5. An angiogram of a double vein graft, one connected just proximal to the posterior descending artery and one attached to the mid anterior descending artery. In this instance the second vein was attached to the side of the first vein, with only one vein connected to the aorta.

tal, mediastinal, musculophrenic, superior epigastric) attached to the main artery (Fig. 1). A typical pedicle has five to nine side branches. As this pedicle is placed over the surface of the heart, the individual side arms are carefully positioned beneath all major coronary branches. From four to nine implants have been made into each heart. Subsequent filling into multiple coronary systems from one pedicle is commonly seen (Fig. 2). With the multiple implant technic, 75 per cent of patients note distinct clinical improvement within 3 months and 95 per cent within 6 months. Despite many merits to the multiple implant system, it offers no immediate help—something which is essential if the late stage patient is to survive surgery.

Our direct coronary surgery, therefore, began 19 months ago. After two initial and successful patch grafts, the vein bypass technic has been used exclusively. The early results were so encouraging that last summer the vein graft technic was expanded and used to all major coronary branches. Vein grafts to left-sided arteries run from the aorta, over the pulmonary artery and down to the appropriate coro-

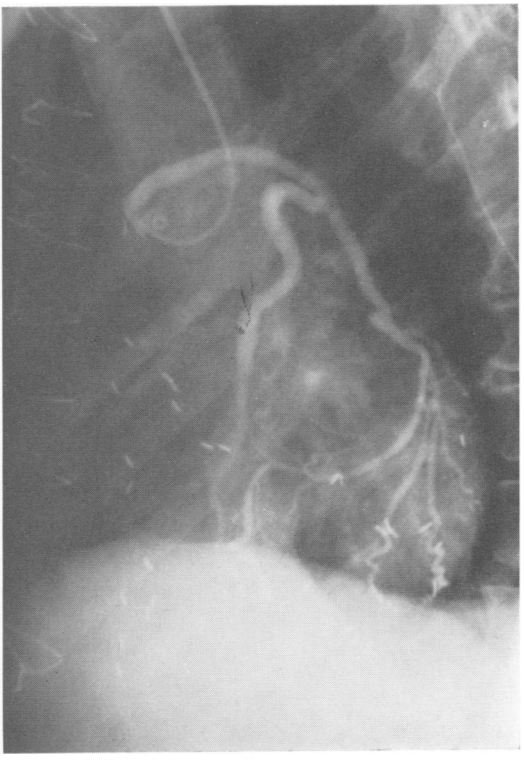

FIG. 6. An angiogram of a double vein graft to circumflex and anterior descending artery. The first vein connects aorta to a large dominant circumflex artery. The second vein runs from the first vein to the anterior descending artery. This procedure is ideal for patients with atherosclerosis of the left main artery or with bifurcation disease.

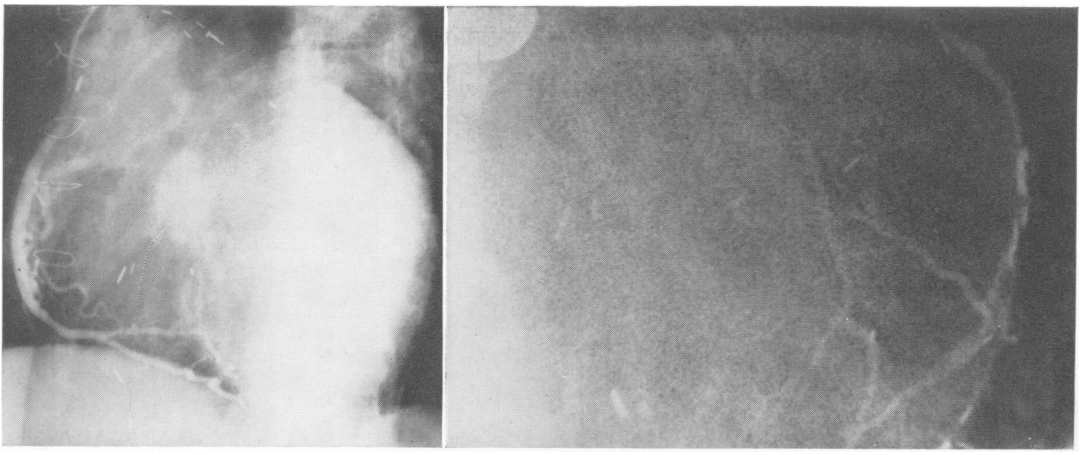

FIG. 7. Combined direct and indirect revascularization. A vein graft was used for a segmentally diseased right coronary and multiple implants were made under the diffusely diseased left coronary. Angiograms were taken 6 months after surgery.

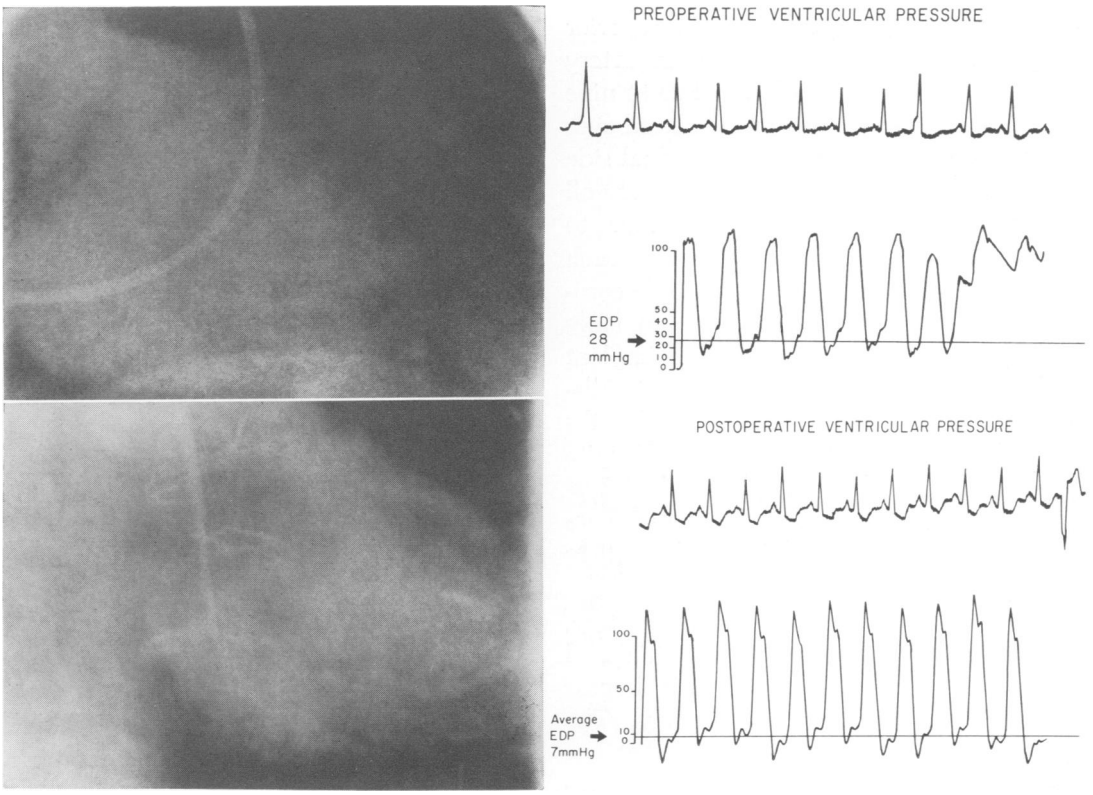

FIG. 8. A 54-year-old man with recurrent heart failure. Two coronaries were occluded and the third severely stenotic. The ventricle was diffusely dilated with an end-diastolic pressure of 28 mm. Hg. At surgery diffuse scar was present throughout the circumference of the left ventricle. A double vein graft was inserted. Postoperatively both veins were open. The ventricle was only slightly smaller, yet pressures were normal with an EDP of 7 mm. Hg. He has remained asymptomatic.

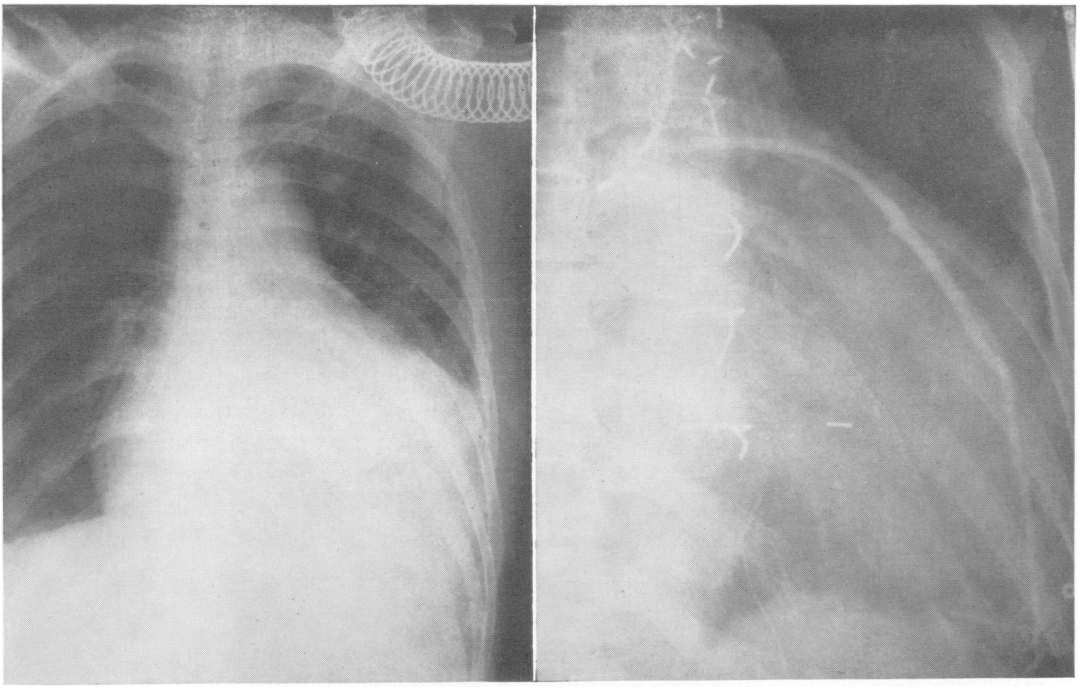

FIG. 9A (left). Preoperative chest film and B (right) postoperative angiograms on 51-year-old hypertensive woman transferred from another hospital after massive right and left heart failure. She had had increasing failure symptoms for 3 years and had been bedridden for weeks. With a constant isuprel infusion the cardiac index was 1.9. Two quick coronary injections confirmed the presence of diffuse atherosclerosis.

nary vessel (Fig. 3). Right-sided grafts run along the atrio-ventricular groove and also attach directly to the aorta (Fig. 4). There is almost no limit of potential arteries to use. Veins can be sutured to the distal anterior descending or even to posterior marginal branches (Fig. 4). Double vein grafts are now used in over 40 per cent of patients and can be used to any combination of arteries (Figs. 5–6). We consider one or two vein grafts inadequate therapy for most patients with two or three vessel disease and, therefore, combined direct and indirect revascularization procedures in most patients (Fig. 7).

This direct approach to coronary flow immediately improves heart function and alleviates most clinical symptoms. Dyskinetic, akinetic or frankly failing myocardium in no way contraindicates surgery. Immediate decrease in heart size, improved contractility, and improved blood pressure and cardiac output are commonly

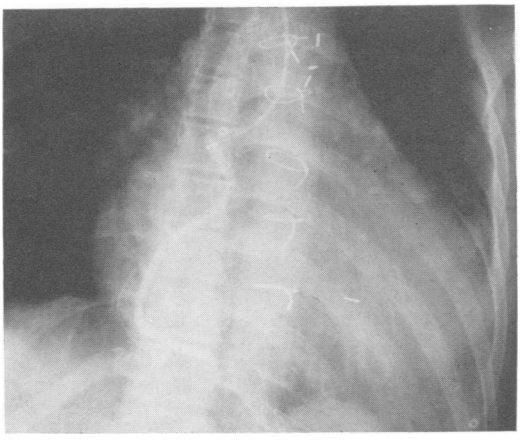

FIG. 9C. A double vein graft was inserted to posterior and anterior descending artery. Her heart remains large, but output is now normal and she remains asymptomatic.

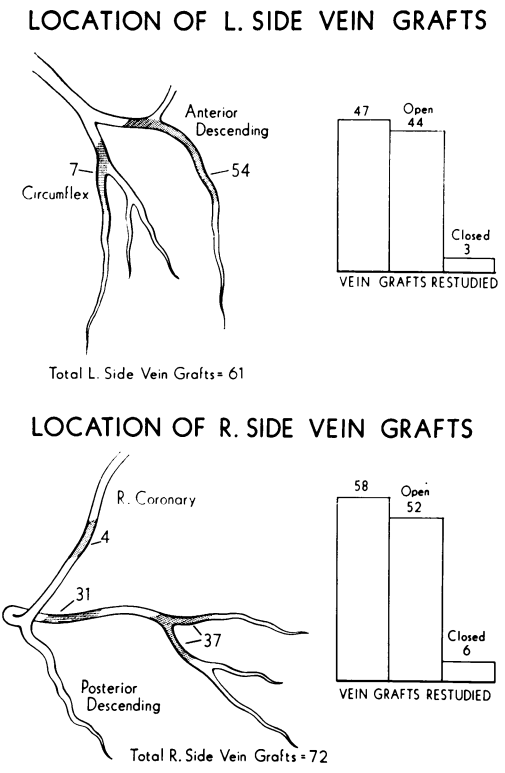

FIG. 10 All veins originate directly from the aorta and have been inserted into areas illustrated above. Note only four grafts have been used proximal to the acute margin of the right ventricle and none into the left main or bifurcation area.

observed in the operating room. These findings have been confirmed in the physiologic laboratory. A marked reduction in end-diastolic pressure and improved output, with or without a change in heart size is often seen (Fig. 8). Angina is almost always absent following surgery. We have not yet been able to define a degree of failure so severe that this alone contraindicates the direct attack on coronary reconstruction (Fig. 9).

Our experience indicates that five factors are important in direct surgery.

(1) *Do not limit grafts to proximal portions of large arteries.* Less than ten per cent of our grafts have been to proximal one third of any coronary system (Fig. 10). While the major stenosis is often proximal, more diffuse disease frequently extends into the middle or distal artery. To limit this surgery to those with isolated obstruction near the origin of major arteries would exclude most patients with coronary atherosclerosis from the benefits of direct surgery.[1, 2]

(2) *Do not work with diseased arteries.* Vein grafts can be made as long as necessary and should be inserted into distal normal arteries. While the major right coronary disease is usually in the upper one third, atheromatous plaques almost always extend into the posterior atrio-ventricular groove. We routinely expose the right coronary to or beyond the origin of the posterior descending artery and insert the vein beyond the last atheromatous plaque. Suc-

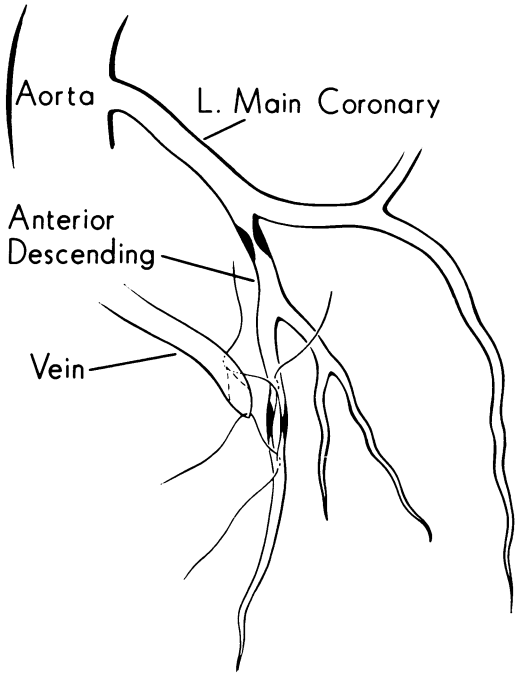

FIG. 11. Veins are usually inserted into an area of normal artery. However, if a second area of atherosclerosis occurs (commonly in the mid-anterior descending artery), the arteriotomy extends across the plaque into normal artery on each end. The vein is sutured as a patch graft always extending the anastomosis to normal artery proximally and distally. With progressive atherosclerosis this maneuver preserves bidirectional flow.

cessful anastomosis in small atherosclerotic arteries cannot consistently be done, but can be done in *normal* 1½ to 2 mm. arteries. We feel the long-term patency of veins inserted distal to all obstruction, and, therefore, into a low-resistance bed, should exceed that of veins placed into widely patent but atherosclerotic vessels (Fig. 10).

Some atherosclerosis invariably involves the proximal coronary. For this reason we have never seen any justification for the vein interposition operation and all veins are attached directly to the aorta.[1, 2]

Occasional exceptions to this rule occur and diseased artery must be used. For example, in an anterior descending artery blocked proximally, a second plaque commonly occurs in the mid portion (Fig. 11). Blood flow from a vein inserted above or below the plaque would eventually be compromised as the disease progressed. An arteriotomy is, therefore, made across this plaque extending into normal artery above and below the lesion. The vein is cut obliquely and sutured end-to-side to the coronary with the anastomosis extending to normal artery above and below the plaque.

(3) *Always do end-to-side anastomosis.* The veins are cut obliquely and the tip is rounded (Fig. 12). The two or three sutures in the corner are critical, but over the remaining arteriotomy the vein acts like a large patch graft. With this type of anastomosis, there has been no angiographic evidence of stenosis at the anastomotic site in any patient, and there has been only one late closure in the entire series.

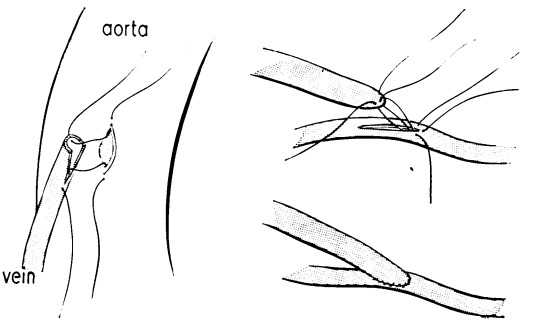

FIG. 12. All veins are sutured end-to-side to the coronary artery. The tip is carefully rounded so that it immediately flares out with proper angulation after the two or three crucial corner sutures are placed. Magnification is never necessary.

(4) *Always work in a dry quiet field.* Consistently successful fine vessel anastomoses cannot be done in a moving bloody target. Most coronary arteries when opened will admit only a 2 mm. dilator. Less than 15 per cent admit a 3 mm. dilator. The aorta is routinely cross-clamped for 15-minute intervals giving a perfectly dry, quiet field. Distal coronary perfusion is never necessary and cannot be done in the fine vessels.

TABLE 1. *Ventricular Aneurysm*

	Aneurysm Size			Diastolic Pressure	
	Small	Med.	Large	Under 20 mm. Hg	Over 20 mm. Hg
1 or 2 vessel 21 patients (2 deaths)	2	5	14	9	12
3 vessel 18 patients (8 deaths)	13	5	0	14	4

TABLE 2. *Mortality with Direct Coronary Reconstruction*

(Excluding Aneurysms)		
Cardiac failure		4
Low output	2	
Arrhythmia	2	
Stress ulcers		3
Technical		3
Pulmonary		2
Sepsis		1
Renal		1
	Total	14 (14%)
Two late deaths		

One hundred-two patients have had direct reconstruction of coronary flow with 14 deaths. In contrast to indirect revascularization when acute infarction was relatively common, non-cardiac complications now cause most morbidity and mortality.

(5) *Do not allow hematocrit to fall below 35.* Cardiac arrest is most commonly associated after hematocrit falls below 32. Coronary patients come off bypass poorly or not at all if the hematocrit is low. Hemodilution in the pump oxygenator should be minimal. A rapid acting diuretic is routinely given as the bypass procedure is nearly finished. Blood is simultaneously pumped in rapidly regardless of venous pressure. With adequate volume and a high hematocrit, termination of bypass is rarely a problem.

Ventricular Aneurysms

Ventricular aneurysm patients are basically managed the same as any other coronary patient except that the aneurysms are removed. Most require simultaneous revascularization with vein grafts and/or arterial implants. The largest aneurysms have invariably been associated with one or two vessel disease and usually with the most severe failure symptoms (Table 1).

Yet, the larger the aneurysm the less the operative risk. In the group with one or two vessel disease and large aneurysms, the risk is under 10 per cent. If all three arteries are over 75 per cent occluded, a large aneurysm has never been seen, yet the operative risk is much higher. In this severely incapacitated group of patients a mortality of 44 per cent is high, but is considerably below that of transplantation. Among the survivors there has been one early death at 6 weeks, no late deaths, and all others are markedly improved. Simultaneous triple procedures (vein graft, aneurysmectomy, arterial implants) are now usually performed in this group.

This type of direct coronary surgery has not been without problems. The operating mortality has not decreased, but the average patient referred and accepted for surgery is considerably more advanced in the disease. Acute infarcts were the most common cause of death when only arterial implants were made. With direct surgery noncardiac complications have been the greatest cause of morbidity and mortality (Table 2). Stress ulcers and technical problems have been the most frequent cause of mortality, while pulmonary problems have been numerous and have caused an occasional death. Major emphasis now is placed on our attempt to reduce these noncardiac complications.

Among all survivors only six patients are not clinically improved, all are in the group receiving implants only. Six patients have died within 2 months of surgery, five of whom had arterial implants only. The sixth death occurred from recurrent anterior infarcts after a posterior vein graft was inserted. Two deaths occurred from 2 to 6 months postoperatively, and no deaths occurred after 6 months.

Summary

1. Of 301 patients with advanced coronary disease who have undergone operation a mortality of 12 per cent has resulted.

2. Direct reconstruction of coronary flow can be achieved in over 90 per cent of all coronary patients. Simultaneous direct and indirect revascularization is used for most patients.

3. End stage coronary disease can nearly always be managed without transplantation.

References

1. Effler, D.: The Surgical Treatment of Myocardial Ischemia. Clinical Symposia (Ciba), 21: 1, 3, 1969.
2. Favaloro, R.: Saphenous Vein Autograft Replacement of Severe Segmental Coronary Artery Occlusion. Ann. Thorac. Surg., 5:4, 335, 1968.
3. Gorlin, R. and Taylor, W. J.: Myocardial Revascularization with Internal Mammary Artery Implantation. JAMA, 207:907, 1969.
4. Proudfit, W., Sones, M., Shirey, E., Fergusson, D. and Sheldon, W.: Revascularization of the Myocardium. Dis. Chest, 55:4, 315, 1969.

Discussion

Dr. Jack A. Cannon (Los Angeles): I congratulate Dr. Johnson on this very admirable series. I can speak of only a much smaller group of patients, perhaps more timidly attacked, but over a much longer number of years which involved a great deal of sweat and tears.

[Slide] This is just a review of our initial experiment at UCLA, which long ago turned out to be a fairly good one insofar as our problems and mortality. You can see that the disease remains and progresses if nothing successful is done about it.

[Slide] In this series there were nine long-term survivors; only four had open vessels. These were treated primarily by endarterectomy only. Initially we did not have the idea of the venous bypass principle.

We had one patient who represented a 7-year survivor who remained completely asymptomatic during that time.

[Slide] Then a series at St. John's Hospital dealt with by Dr. James McKeech, Rodney Smith and myself. We have now 58 operations performed on 52 patients. The over-all surgical mortality is 23 per cent.

If you will allow us to look at these in two groups, the first 29, we made some errors and had some problems. If you will allow us to recognize these and insert a corrected mortality, it becomes something more respectable. In our second 29 operations, the mortality has been 9 per cent.

The policy of having these patients agree that they will all be restudied, 21 of the 43 survivors have been restudied; 6 have reoccluded. Oddly enough, one remains angina-free though reoccluded. This probably represents improvement in his inner coronary collateral. We have operated on any patient who reoccluded where a distal tree was demonstrable. Our late failure rate is 9 per cent.

[Slide] In summary, 43 of 52 patients survived 3 months to 7 years. Forty or 93 per cent of the survivors are either asymptomatic or significantly improved. Thirty-seven or 86 per cent have negative treadmill tests and three are asymptomatic with positive treatmill tests.

[Slide] An example. Here is an angiogram of a patient with rather extensive involvement of his right coronary.

[Slide] Showing in a later projection very poor filling of the myocardium.

[Slide] He was treated by endarterectomy, revascularization of the distal tree and a very marked improvement in the perfusion into the left main coronary.

[Slide] Showing increased improvement in the entire heart.

[Slide] Because of his profound left involvement, an internal mammary artery implant was performed.

[Slide] Here is the implant going into the myocardium.

[Slide] And our problem with the implant is that we never do find really impressive distal perfusion and these patients never do, in our experience, show a negative treadmill test.

Dr. Frank Spencer (New York):

[Slide] I would like to present briefly some data to support Dr. Johnson's hypothesis that direct anastomosis may be much more frequently possible than it has been considered in the past. These studies were all done by Dr. George Green in our Department of Surgery at the New York University Medical Center.