

The Distal Coronary Bypass

GEORGE C. MORRIS, JR., M.D., JIMMY F. HOWELL, M.D., E. STANLEY CRAWFORD, M.D.,
GEORGE J. REUL, M.D., DON W. CHAPMAN, M.D., H. LISTON BEAZLEY, M.D.,
WILLIAM L. WINTERS, M.D., PAUL K. PETERSON, M.D.*

*From the Department of Surgery, Baylor College of Medicine and
The Methodist Hospital, Houston, Texas*

IN the past several years a method of restoring normal or nearly normal blood flow to the ischemic heart has evolved in our and other centers.^{3, 6, 7, 8, 9, 11, 12} The technic in its simplest form consists of forming bypasses of reversed saphenous veins from the ascending thoracic aorta to the more distal undiseased areas of the three coronary arteries. Because of the great frequency of coronary artery disease and the obvious effectiveness of the procedure in restoring myocardial blood flow with minimal risk, the operation has become a daily routine. In retrospect one wonders why this most logistically important treatment of heart disease developed so late in the past two decades of cardiovascular surgery. The reasons are not hard to find: The development of high quality arteriography followed Sone's report of selective injection method.¹⁰ Pump oxygenators required refinements to allow long periods of bypass. And finally, acceptance of ischemic arrest was necessary to provide a still and dry field for the terminal anastomosis of vein grafts to one and two millimeter arteries. Furthermore we, as others, repeated mistakes and failed to use lessons learned in other occlusive areas such as the iliac and femoral arteries. Blind endarterec-

tomies, small patch grafts, resection and graft interposition were all tried with different results.^{1, 2, 4} The first successful vein bypass in our center was performed in 1964, and consisted of a single bypass from the ascending thoracic aorta to the anterior descending coronary artery in a 42-year-old man with 75% narrowing of the left main coronary artery.⁵ The patient had an increase of cardiac output from 6.6 l./min. to 8.6 l./min. and is at present asymptomatic. However, for reasons mentioned, routine adaptation of coronary bypass occurred only in the past 2 years.

Selection of Patients

Ages of our patients have ranged from 28 to 73 years, and although the average age was 51 years, we do not feel geriatric patients should be denied the operation (Table 1). Men exceeded women by a ratio of more than 10 to 1, and it is interesting that the majority of these women had metabolic problems with hypercholesterolemia and hyperlipidemia (Fig. 1). Angina was a significant symptom before operation in 158 of the 161 patients and was combined with symptoms of congestive heart failure in 25% (Table 2). Elevation in end-diastolic pressure was present in 48.2% of patients and was over 20 mm. Hg in 13.5%. In this connection, nearly a quarter of patients had non-contractile areas or areas of paradoxical contraction in the left ventricle and six had large left ventricular aneurysms requiring resection.

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* Department of Surgery, Baylor College of Medicine and the Methodist Hospital, Houston, Texas.

TABLE 1. *Distal Coronary Bypass—
Age and Sex Incidence*

Sex	Number	Percentage
Male	147	91.3
Female	14	8.7
Total	161	100.0

Age Group	Number of Patients in Group
28-30	2
31-40	13
41-50	64
51-60	59
61-70	22
71-73	1
Total	161

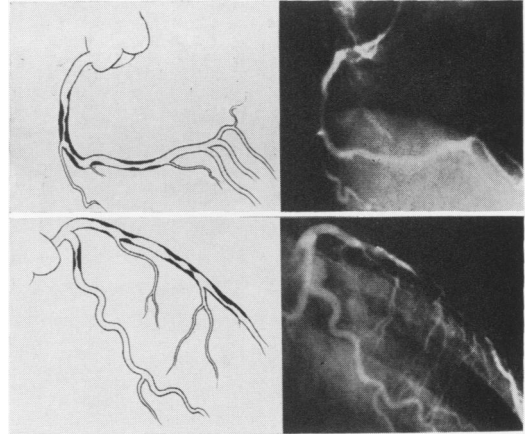
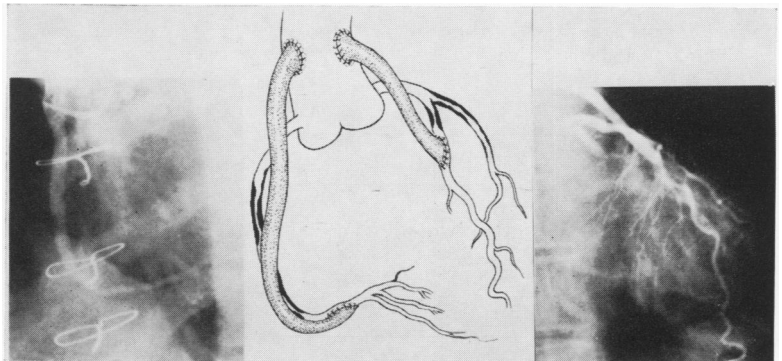


FIG. 1. a) Preoperative selective cine coronary arteriograms and drawings showing extensive arteriosclerotic areas of narrowing in coronary arteries of 42-year-old woman with intractable angina, hypercholesterolemia and hyperlipidemia.

Evidence of previous myocardial infarction was noted in more than half of the patients (59.6%). The only relative contraindication to operation was recent myocardial infarction. Six patients developed preoperative infarctions in the hospital. Operation was deferred for 6 to 8 weeks and there were no deaths after operation. It has been our impression that this group, however, had the highest incidence of postoperative arrhythmias. Commonly encountered associated conditions included hypertension, peripheral vascular disease, hyperlipidemia, diabetes, peptic ulcer and narcotic addiction (Table 3). Eleven patients had previous Vineberg procedures, some of which were functioning, and three

had previous unsuccessful direct reconstructions (Fig. 2). Simply stated, patients with severe occlusive coronary artery disease confirmed by arteriography were selected to undergo operation; those with very recent infarctions were temporarily excluded. Arteriographic categorization defines four vessels; right, left anterior descending, circumflex, and left main; degree of stenosis or complete occlusion, and determines the extent of vascular involvement, single, double, triple or quadruple (R, LAD, Cx, LM). The vast majority (88.9%) had evidence of severe multi-vessel disease. A point of significance to us has been the common finding at operation of a patent vessel beyond areas of

FIG. 1. b) Postoperative arteriograms and drawings showing vein bypass from ascending thoracic aorta to posterior interventricular branch of right coronary artery and to left anterior descending coronary artery distal to diagonal branch.



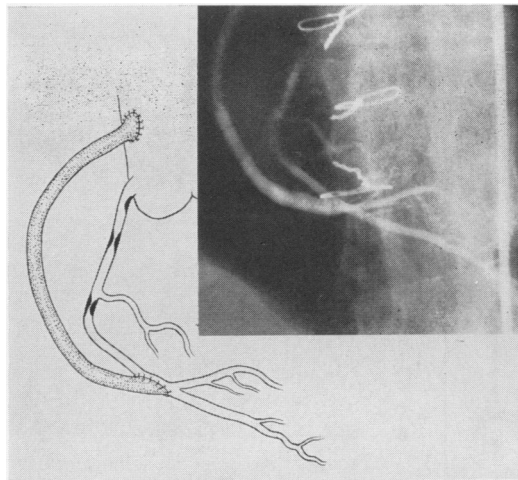


FIG. 2. a) Drawings and selective arteriograms in 39-year-old man with extensive triple vessel coronary occlusive disease who had functioning internal mammary implant to left ventricle, but severe recurring angina required distal right coronary bypass for relief of symptoms.

complete occlusion which fail to visualize with preoperative arteriography. This is particularly cogent of the right vessel in which, with rare exceptions, a patent marginal or posterior interventricular branch suitable for terminal anastomosis is found despite arteriographic absence of patent distal vessels. Similarly on the left, if there

TABLE 2. *Distal Coronary Bypass—Symptoms*

Symptoms*	No. Patients	%
Intractable angina	50	31.1
Angina and congestive heart failure	12	7.4
Angina and myocardial infarction	68	42.2
Congestive heart failure	3	1.9
Angina, myocardial infarction and congestive heart failure	28	17.4
Total	161	100.0
Functional Class	No. Patients	%
I	6	3.7
II	51	31.6
III	75	46.6
IV	29	18.0
Total	161	100.0

* Duration of symptoms—range 1 month to 16 years.

TABLE 3. *Distal Coronary Bypass—Associated Diseases*

Disease	Number
Peripheral vascular disease	21
Hypertension	29
Diabetes	13
Valvular heart disease	5
Hyperlipemias	14
Peptic ulcer	8
Gout	2
Portal cirrhosis	1
Narcotic addiction	4
Renal disease	2
Leukemia	1
Malignant melanoma	1

is no evidence of large infarction with an akinetic area or frank aneurysm, the terminal elements of the anterior descending and circumflex commonly will be patent and acceptable despite failure of terminal visualization. Demonstration of high grade stenosis in the left main coronary artery constitutes a relative emergency for opera-



FIG. 2. b) Operative photograph showing distal vein bypass to posterior interventricular branch of right coronary artery.

tion since most of our preoperative mortalities have been in this group (Fig. 3).

Surgical Technic

Generous lengths of saphenous vein are procured at the same time the heart is exposed by median sternotomy. In the very ill, femoral arterial and venous cannulation allows immediate partial cardiopulmonary bypass, otherwise venous cannulation is made through separate caval catheters. Decompression of the left heart now appears preferable through a left atrial catheter rather than through the apex of the ventricle. Many patients have diseased ilio-femoral arteries and are best cannulated for arterial return through the aortic arch near or distal to the innominate artery (17%). Heparin is given initially at 5 mg./kilo and additional doses added appropriate to perfusion time. Disposable bubble oxygenators are primed with 5% dextrose.

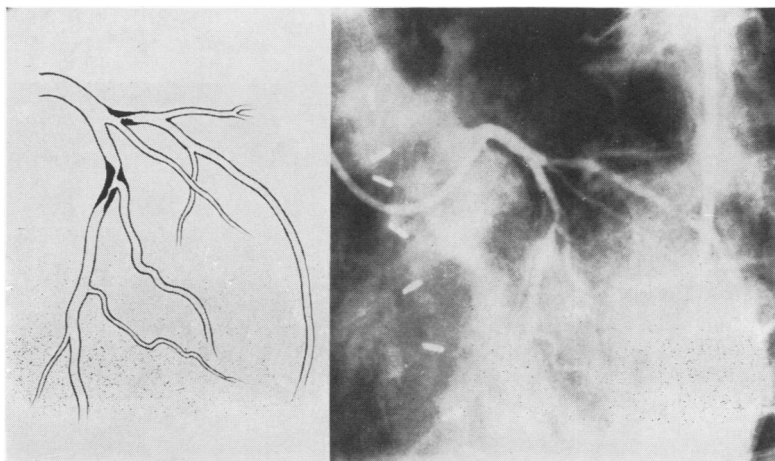
In patients receiving multi-vessel bypass, all terminal anastomoses are completed initially with individual periods of anoxic arrest for each anastomosis. In multi-vessel bypass the order of terminal anastomosis is circumflex, anterior descending and right. The circumflex vessel is exposed by lifting the apex of the heart upward and toward the patient's right shoulder. With ischemic arrest coronary tapes or clamps



FIG. 3. Selective coronary arteriogram showing high grade stenosis in left main coronary artery. This 57-year-old man died suddenly while on bypass 2 days before scheduled operation. Lesions such as this should constitute a relative emergency for correction.

are generally unnecessary and dissection is sufficient to perform arteriotomy. The bevel of the vein and the size of the arteriotomy are dependent on the anticipated attitude of the bypass when functioning. Continuous 6-0 polypropylene has replaced 5-0 polyethylene for suture. Interrupted sutures are occasionally useful in difficult anastomoses. The integrity of the terminal anastomosis is tested under heparinized saline pressure before discontinuance of ischemic arrest. The heart is allowed to perfuse for a short period between per-

FIG. 4. a) Arteriogram and drawing before operation in 43-year-old man with proximal stenotic lesions in both branches of left coronary artery.



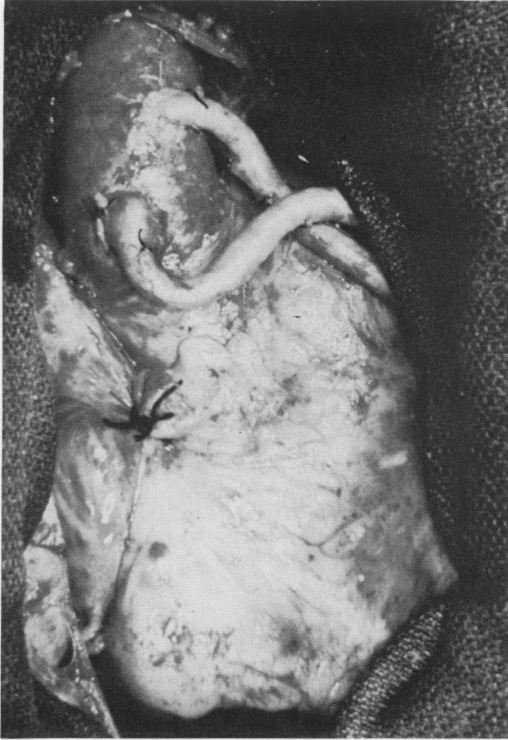


FIG. 4. b) Operative photograph showing origin of vein bypasses to anterior descending and circumflex coronary arteries.

formance of each terminal anastomosis. Bi-directional anastomotic competence is checked with dilators and with saline injection through the vein. When all terminal anastomoses are completed, separate proximal anastomoses are made to the ascending thoracic aorta using an exclusion clamp (Fig. 4). Removal of all air in the

TABLE 4. *Distal Coronary Bypass—Operation*

Procedure	No. Patients	%
Right bypass (main)	64	39.8
Right bypass (marginal)	3	1.8
Right bypass (septal)	1	0.6
Right bypass (overlying)	11	6.8
Right and LAD (double)	29	18.0
Right, LAD, and Cx (triple)	2	1.2
LAD	29	18.0
Cx	7	4.3
LAD and Cx (double)	4	2.5
Right-Gas	2	1.2
Right Gas and LAD bypass	1	0.6
Right Gas and Cx bypass	0	0.0
Right Gas and right bypass	1	0.6
Right bypass and Cx bypass	7	4.3
Total	161	100.0

Concomitant Procedures

Procedure	No. Patients	%
Resection ventricular aneurysm	6	3.7
Valve replacement	2	1.2
Vineberg with right bypass	2	1.2

bypass avoids temporary rhythm disturbances. The rarity of gas endarterectomy in this series is a result of our ability to find a patent marginal or posterior interventricular branch in most terminally occluded right coronary arteries (Table 4). Significant features required in early post-operative care are ventilatory assistance

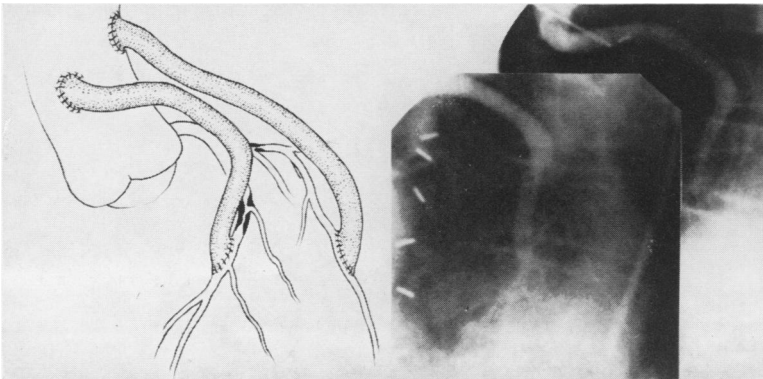


FIG. 4. c) Arteriograms and drawing showing functioning vein bypass grafts to distal areas of anterior descending and circumflex branches of left coronary artery.

TABLE 5. *Distal Coronary Bypass—Mortality*

Deaths	No.	%	Cause of Death
Operative	4	2.5	1) Failure to come off pump 2) Dissection femoral artery 3) No cardiac output 4) Unknown
Immediate Postoperative (0-5 days)	6	3.7	1) Cardiac tamponade (1 day) 2) Acute myocardial infarction (3 days) 3) Intractable congestive heart failure (3 days) 4) Low cardiac output (30 min.) 5) Ventricular fibrillation (2 days) 6) Acute myocardial infarction (1 day—occluded graft)
Hospitalization (5 days to Discharge)	4	2.5	1) Renal failure-sepsis (45 days) 2) Myocardial infarction (6 days) 3) Sternal dehiscence-hemothorax (9 days) 4) Acute myocardial infarction (Anterolateral-6 days)
Post-Hospitalization	2	1.2	1) Cardiac arrest (131 days) 2) Unknown (27 days)

for at least 12 hours, maintenance of normal hematoacrit, high normal central venous pressure, and forced diuresis.

Results

One hundred and sixty-one patients had distal coronary bypasses performed by the three senior authors in which the total hospital mortality was 8.7% (Table 5). Early in this 2-year experience there was a proclivity to single bypass, but the occasional occurrence of postoperative infarction in myocardium distal to uncorrected diseased coronaries soon led to multi-vessel bypass in the usual patient with multi-vessel disease. With this approach we hope to reduce the more common cause of mortality—infarction in an unbypassed area of myocardium (four patients). Three patients died of left ventricular failure. One patient died from retrograde dissection of a femoral arterial return cannula. The more frequent use of aortic cannulation hopefully will obviate this complication. Other single causes of death included late sternal disruption, renal failure, and ventricular fibrillation.

Intraoperative flow studies with an electromagnetic flow meter were performed

in 23 grafts (Table 6). Flow rates ranged from 20 ml./min. to 160 ml./min, and were generally higher in bypasses to divisions of the left coronary vessel than to the distal right coronary vessel or its divisions.

Postoperative arteriographic studies were performed in 85 patients (Table 7). Eighty-five of 96 grafts studied were patent (89%). Two patients had both early (within 3 months) and late (after 1 year) postoperative arteriograms in which there was no evidence of change or deterioration of the saphenous vein autografts (Fig. 5).

Certainly the ameliorative effect of any operation on prior angina adds very little significant documentation to the physiologic efficacy of the procedure, but some postoperative observations have been interesting. Permanent disappearance of angina was observed in 78% of patients and

TABLE 6. *Distal Coronary Bypass—Postoperative Graft Blood Flow Studies*
(Electromagnetic Flow Meter)

Grafts	No. Grafts	Flow	Range
Right grafts	14	66 cc/min	28-150
LAD	7	84 cc/min	20-160
Circumflex	2	78 cc/min	60-95

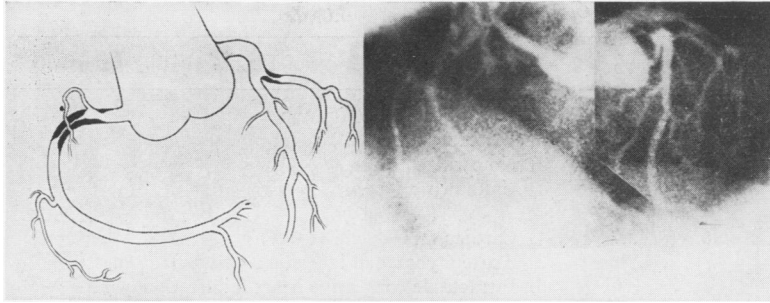


FIG. 5. a) Arteriograms and drawing showing proximal occlusion right coronary artery and stenosis left circumflex.

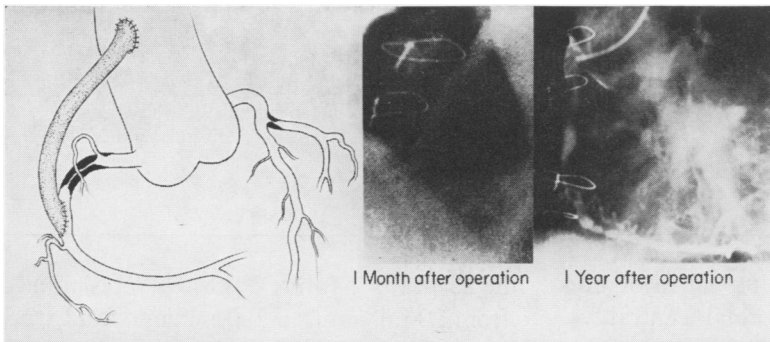


FIG. 5. b) Arteriograms and drawing showing bypass graft to right coronary artery. Comparison of arteriograms 3 months and 12 months after operation shows no degenerative changes in reversed saphenous vein autograft.

significant decrease in angina in all but six patients. Patients still exhibiting some angina (18%) required significant stimulation to bring it on, usually in the form of strenuous exercise. Most of these patients had what are considered to be incomplete operations, viz. single bypass in the presence of multi-vessel disease. In the group of patients with congestive heart failure prior to operation, 82% were improved in this respect, 9% were unchanged, and 9% were worse.

Discussion

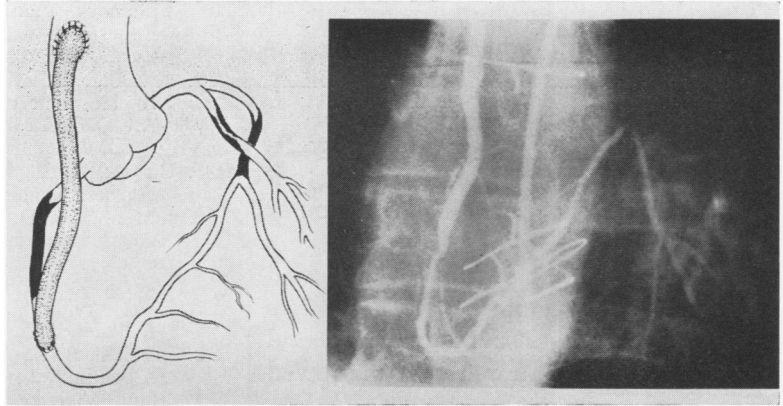
Only time and actuarial studies will provide undisputed proof of the efficacy of the distal coronary bypass. However, at present cardiologists consider this form of treatment to be optimally effective and adequate for patients with occlusive coronary artery disease. One of the most impressive observations in our experience has been that the preoperative mortality approaches the operative mortality (Fig. 3). The low intraoperative mortality (2.5%) stands out more vividly in this series in which almost no one was considered too sick to undergo operation. The very high patency rate of the grafts (89%) is even more significant; these grafts fill not only radicals of the vessel to which they are attached, but also the large pre-existing collateral beds between the three coronary arteries (Fig. 6). Finally, the long-term arteriograms performed more than 1 year after operation tend to document the stability of these grafts (Fig. 7). Further improvements in technic should improve present good re-

TABLE 7. Distal Coronary Bypass—Postoperative Selective Cine Coronary Arteriograms

Postoperative Period	Patent Grafts	Occluded Grafts	Total	%
Within 1 month	62	9	71	87.0
One to 6 months	19	2	21	90.4
Six to 11 months	2	0	2	100.0
Twelve to 23 months	2	0	2	100.0
Total	85	11	96	89.2

This includes total number of grafts studied, of which 13 were double bypasses. Of these, 3 patients demonstrated occlusion of one graft (and patency of the other).

FIG. 6. Drawing and arteriogram in 48-year-old man with chronic myelogenous leukemia showing functioning distal right coronary bypass filling distal elements of proximally occluded left circumflex artery.



sults since the percentage of very sick patients will probably not increase. Most impressive are those with failing cardiac output which requires partial bypass before the start of operation and yet reverted to a normal hemodynamic state at the end of the procedure.

Because there is no indication that ischemic arrest contributes to the cause of death and the success of operation is highly dependent on the integrity of the distal anastomosis, we use it almost routinely for this portion of the procedure. Not only is the still, dry field a great asset in this critical anastomosis, but the empty coronary artery does not require extensive dissection nor the use of occluding tapes or clamps.

Myocardial revascularization of the Vineberg type has been utilized only twice in this series. There appears too little to gain

(flow rates of less than 15 ml./min. months later) and too much to lose (muscle injury in and about the tunnel) by use this procedure.¹³ Our previous experience indicated a hospital mortality of nearly 15%.

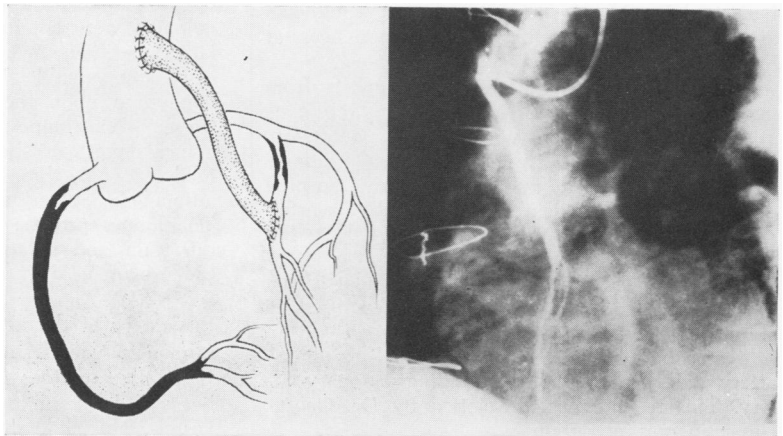
The greatest problems that we foresee are logistic and related to the capacity of catheter laboratories and operating rooms to manage the numbers of patients with coronary artery disease.

Summary

One hundred and sixty-one patients underwent distal coronary artery bypass procedures with reversed saphenous vein autografts.

Total hospital mortality was 8.7% despite almost no exclusion of very ill or bad-risk patients as operative candidates.

FIG. 7. Drawing and arteriogram performed one year after operation in 51-year-old man with vein bypass to left anterior descending coronary artery.



Operative flow rates in the grafts ranged from 20 to 160 ml./min. and were generally higher in bypasses to the left coronary artery.

Postoperative arteriography in 96 grafts disclosed a patency rate of 89% and studies after 1 year showed no deterioration of grafts.

Complete revascularization of the usual heart with multi-vessel disease by multiple grafts is favored over single grafts to avoid infarction in areas supplied by narrowed unbypassed coronary arteries.

Addendum

Since submission of this report, an additional 253 operations have been performed. Hospital mortality in this series of 314 cases is 6.6%.

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DISCUSSION

DR. FRANK C. SPENCER (New York City): I enjoyed Dr. Morris' presentation and would like to describe briefly some of our experiences at New York University.

It is of particular interest that reports from several groups are almost identical with reference to favorable experiences with this new operation. At New York University more than 80 patients have been operated upon with eight hospital deaths and five late deaths. The operative mortality of 10% is similar to the 9% reported by Dr. Morris.

One technical difference in management is that the internal mammary artery has been used in about 50% of the patients, performing an end-to-side anastomosis between the internal mammary artery and the anterior descending coronary artery. This technic was developed by Dr. George Green in our institution.

[Slide] Magnification of the operative field has been of particular interest to us. A number of devices used by ophthalmologists and otolaryngologists were not found satisfactory. The binocular loupes shown in this illustration have been extremely valuable. These are individually made, depending upon the optical requirements of the surgeon. The loupes magnify to four power, with a focal length of about 15 inches and a depth of field of two to three inches. This has been a great adjunct in operating upon 1 to 2 mm. vessels. The loupes provide an adequate degree of magnification and avoid the restrictions inherent in the use of an operative microscope.

[Slide] Another significant future question is the choice of the internal mammary artery or the saphenous vein for a graft. The principal question is whether there will be a significant difference between longterm patency rates between the two vessels. This slide shows an internal mammary ar-