Coronary artery surgery: indications and recent experience

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Summary

The comprehensive experience of coronary artery surgery in a Cardiothoracic Unit over a 31-month period is reviewed. Hospital mortality for elective bypass grafting was 3.9% overall and 2.5% in those with good pre-operative left ventricular function. Major influences on hospital mortality were pre-operative left ventricular function, extent of coronary artery disease and extent of the surgical procedure undertaken in terms of number of aortocoronary grafts inserted, coronary endarterectomy and particularly concomitant valve surgery or aneurysm resection.

Follow-up experience shows 74% of grafted patients to be symptom-free and 85% symptomatically improved one year after surgery with 70% symptom-free and 80% improved at two years. Early post-operative deaths appear related to early graft closure and recurrence of symptoms postoperatively to late graft closure or progression of coronary disease in the native circulation. The study provides a guide to the relative risks of coronary artery surgery for symptomatic coronary artery disease and expected symptomatic results in the early follow-up period.

Introduction

The construction of aortocoronary bypass grafts, introduced by Favaloro and his colleagues in 1967 (Favaloro, 1968, 1969) as a remedy for obstructive coronary artery disease, is now commonplace. The indications for such surgery range from the most conservative - failed medical management of a severely limited patient - to an aggressively prophylactic approach. The latter aims to conserve

irreplaceable myocardium (i.e. prevent infarction) and to prolong life. The rationale for surgery as a therapeutic manoeuvre depends, therefore, for the conservative, on a sustained symptomatic improvement, and for the most aggressive, on an increase in life expectancy. A low operative mortality rate and a high long-term graft patency rate thus necessarily become of increasing significance as the indications become less conservative. The extent of coronary arterial disease and the degree of irreversible damage to the myocardium before surgery are important determinants of early mortality and the functional results.

Reports from the larger cardiac centres in America claim a hospital mortality below 6% for uncomplicated bypass surgery with improvement in 80-90% of patients surviving operation. These series tend to be selective and do not give an overall picture of the role of coronary artery surgery in the context of a general cardiac surgical programme. The authors now report the comprehensive experience of coronary artery surgery in a cardiothoracic unit over a consecutive 31-month period.

Patients

Following clinical assessment and diagnostic cardiac catheterization, patients were considered for surgery on the following indications.

Symptomatic

- (1) Stable angina refractory to medical treatment.
- (2) Unstable angina refractory to medical treatment.

Anatomical

- (1) Significant left main stem or equivalent coronary artery disease.
- (2) Demonstration of significant obstructive coronary artery disease in patients undergoing

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investigation before surgery for: (a) complications of myocardial infarction (mitral regurgitation and left ventricular aneurysm); (b) other valve disease (aortic or mitral valve disease); (c) ventricular dysrhythmias refractory to medical therapy.

Patients were not excluded from surgery on the basis of poor pre-operative left ventricular function if angina was the dominant symptom and the coronary artery anatomy was suitable.

Symptoms were graded according to the New York Heart Association (NYHA) applied to the limiting symptom either angina or dyspnoea. Previous myocardial infarction was established on either a documented hospital admission with a discharge diagnosis of myocardial infarction or on the presence of pathological Q waves on the resting electrocardiogram. Heart size was assessed from a standard postero-anterior chest X-ray. Cardiac catheterization was in most cases an elective procedure with full right and left heart catheterization. Left ventricular ciné-angiograms were taken in the right anterior oblique position. In addition, either a left anterior oblique or left lateral view was obtained. The left ventricular ciné-angiogram was graded visually for:

I normal contraction; II localized dyskinesia of one wall of the ventricle; III localized dyskinesia of two or more walls of the ventricle; IV generalized severe hypokinesia with or without localized regions of dyskinesia.

The end-systolic and end-diastolic volumes and ejection fraction were calculated from the left ventricular ciné-angiogram using a light pen/computer system (Chatterjee *et al.*, 1971).

Coronary arteriography was performed by the Judkins' technique using multiple views of each coronary artery. Vessel stenosis was considered significant if the luminal diameter of the main stem or major branches of a coronary artery were reduced by 50% or more.

The technique of coronary artery surgery is described elsewhere (Favaloro, 1968, 1969). One-

hundred and ninety-three patients had aortocoronary bypass grafts. The patients comprised 162 males aged 31–75 years (mean 50.3 years); and thirty-one females aged 42–75 years (mean 55.1 years). One hundred and forty-six patients had aortocoronary bypass grafts alone; twenty-six, resection or plication of left ventricular aneurysms; nineteen, surgery to aortic or mitral valves; and two, resection of infarcted myocardium in addition to bypass grafts. Operations performed are shown in Table 1. One patient had a mitral annuloplasty in addition to aneurysm resection and one had mitral valve replacement in addition to resection of infarcted myocardium. A total of forty-seven patients had complex surgical procedures.

TABLE 1. Operative procedure

Procedure	No. of patients
Aortocoronary bypass grafts alone	146
Coronary endarterectomy	61
Left ventricular aneurysm surgery	26
Aneurysm resection	21
Aneurysm plication	5
Valve surgery	19
Aortic valve replacement	8
Aortic and mitral valve replacement	2
Mitral valve replacement	2
Mitral annuloplasty	2
Infarct resection	2
Total	193

In all, 419 vessels were grafted using 416 grafts (sequential grafts to two vessels in the same vascular territory were employed in three cases). Reversed saphenous vein was used for 404 grafts and internal mammary artery for 12 grafts. Graft numbers and distribution are outlined in Table 2. Coronary endarterectomy was performed in seventy-three patients overall, the distribution of the vessels endarterectomized is shown in Table 3.

Of 146 patients having bypass grafts alone, 144 had refractory angina pectoris of which 114 (78%)

TABLE 2. Aortocoronary bypass graft numbers and distribution

Aortocoronary bypass grafts	Grafts alone	Complex surgery
Single graft	30	16
Left anterior descending coronary artery	19	10
Left circumflex coronary artery	0	4
Right coronary artery	11	2
Double grafts	59	20
Triple grafts	49	8
Quadruple grafts	8	3
Total	146	47

TABLE 3. Coronary endarterectomy

	Grafts alone	Complex surgery
Patients	61	12
Vessels endarterectomized	77	13
Left anterior descending coronary artery	18	4
Left circumflex coronary artery	4	—
Right coronary artery	55	9

were NYHA class III or IV and thirty NYHA class II. Two patients had no angina, one investigated electively following myocardial infarction and the other with recurrent ventricular arrhythmias. Of the forty-seven patients requiring complex surgical procedures, two suffered recurrent ventricular arrhythmias the remainder were limited by angina or dyspnoea; thirty-eight (81%) were NYHA class III or IV and seven NYHA class II. The two patients requiring resection of infarcted myocardium were in severe left ventricular failure one due to an inferior false aneurysm, and the other to severe mitral regurgitation secondary to papillary muscle dysfunction.

Eleven patients were under treatment pre-operatively for diabetes mellitus and twelve had been treated for persistent hypertension.

Eighty-three patients (43%) had no evidence of previous myocardial infarction, while 103 (53.4%) had evidence of old myocardial infarction (sixty-four, one previous infarct; and thirty-nine, two or more infarcts) and seven (3.6%) were operated on within 2 months of acute myocardial infarction.

The heart size on chest X-ray was normal in 102 patients. Slight cardiac enlargement was present in fifty-three, moderate in thirty-three and severe in five.

Results

Hospital mortality: (Table 4)

Twenty-one of the 193 patients in this series died during the in-hospital period. Ten deaths occurred at operation and eleven in the postoperative period; of the latter, nine died within 14 days of operation and two after a protracted postoperative course. In all the ten patients dying at operation, cardio-pulmonary bypass could not be withdrawn owing to either intractable arrhythmias or inability of the left ventricle to sustain an adequate cardiac output without support. Of this group seven of ten had complex surgery of whom three had resection of left ventricular aneurysms, two aortic valve replacement, one aortic and mitral valve replacement and one resection of infarcted myocardium and mitral valve replacement undertaken for cardiogenic shock and severe mitral regurgitation 24 hr after the onset of

acute myocardial infarction. A further patient with a 90% stenosis of the left main coronary artery was operated on as an emergency following probable infarction at the time of cardiac catheterization. At post-mortem there was clear evidence of recent infarction in only two cases who had sustained infarction before surgery and all twenty grafts were patent.

The eleven deaths occurring in the postoperative period include six patients where death was due to poor left ventricular pump function with a persistently low cardiac output and its complications, one due to pulmonary embolism and four due to intractable ventricular fibrillation. Of this group, six of eleven had complex surgery comprising five who had resection of left ventricular aneurysms and one mitral valve replacement. At post-mortem there was evidence of recent infarction in six cases and, of twenty-nine grafts inserted, eighteen (62%) were patent.

For uncomplicated elective bypass grafting hospital mortality was 3.9% overall and 2.5% for those with good pre-operative left ventricular function (ejection fraction greater than 0.55) – Table 4. When more complex surgery was undertaken mortality was substantially higher – 21.1% for combined valve surgery and bypass grafting and 30.8% for combined aneurysm surgery and bypass grafting. Over a similar period twelve patients had aneurysm surgery without bypass grafting with a hospital mortality in this group of 16.7%.

The influence of clinical features, pre-operative left ventricular function and extent of coronary artery disease on hospital mortality in patients having bypass grafts alone is considered in Tables 5, 6 and 7. The influence of various clinical features is considered in Table 5. Except in the oldest age group (60–69 years), age appears to have little influence while mortality was increased in female patients and when there was a pre-operative history of hypertension or diabetes mellitus.

Pre-operative left ventricular function is considered in Table 6. The figures demonstrate increased early mortality with deterioration of left ventricular function whether reflected in heart size on the pre-operative chest X-ray, evidence of old or recent myocardial infarction, the appearance of the left

TABLE 4. Influence of operative procedure on hospital mortality

Procedure	Mortality (%)			
Aortocoronary bypass grafts alone	8/146	5.5%		
Elective surgery (good left ventricular function, ejection fraction ≥ 0.55)			2/81	2.5%
Elective surgery (all patients)			5/127	3.9%
Emergency surgery			3/19	15.8%
Complex surgery	13/47	27.7%		
Left ventricular aneurysm surgery			8/26	30.8%
Valve surgery			4/19	21.1%
Infarct resection			1/2	50%
Aneurysm surgery without grafts			2/12	16.7%

TABLE 5. Influence of clinical variables on hospital mortality for aortocoronary bypass grafting

Clinical features	Mortality		%
Age (years)			
30-39	1/16		6.3%
40-49	2/46		4.4%
50-59	1/68		1.5%
60-69	4/16		25%
Sex			
Male	6/121		5%
Female	2/25		8%
Hypertension	1/9		11.1%
Diabetes mellitus	2/10		20%

TABLE 6. Influence of pre-operative left ventricular function on hospital mortality for aortocoronary bypass grafting

	Mortality		%
Heart size on chest X-ray			
Normal/slight enlargement	5/127		3.9%
Moderate/severe enlargement	1/20		5.0%
Previous myocardial infarction			
None	2/72		2.8%
Old	4/69		5.8%
Recent (within 2 months)	2/5		40.0%
Left ventricular ciné-angiography			
I Normal	4/75		5.3%
II One wall dyskinetic	2/35		5.7%
III Two or more walls dyskinetic	2/24		8.5%
IV Generalised severe hypokinesia	0/12		0
Left ventricular ejection fraction			
≥ 0.55	3/83		3.6%
0.25 to 0.54	4/47		8.5%
< 0.25	0/5		0
Left ventricular end-diastolic pressure			
≤ 12 mmHg	5/126		4.0%
< 12 mmHg	2/14		14.3%

ventricular ciné-angiogram, left ventricular ejection fraction or left ventricular end-diastolic pressure.

The extent of coronary artery disease and the complexity of the surgery required to provide relief is outlined in Table 7. Early mortality increases progressively with the number of vessels diseased and is substantially higher in the presence of left main coronary artery disease compared with two and three vessel coronary artery disease without left main coronary artery involvement.

Mortality also rises progressively with the number of bypass grafts inserted and endarterectomy has an unfavourable influence presumably reflecting more severe coronary disease.

Emergency surgery carries a higher mortality than elective surgery. In this series emergency surgery was undertaken in twenty-three patients (nineteen had bypass grafting alone). Thirteen of the patients had crescendo angina defined as angina of increasing frequency and severity culminating in prolonged rest pain, refractory to medical therapy, with no enzymatic or electrocardiographic evidence of myocardial infarction, and in the presence of significant coronary artery disease. None of this sub-group died. Seven patients were operated within 2 months of myocardial infarction (four within 24 hr of the onset of infarction) for complications of acute myocardial infarction either persistent pain or left ventricular failure - three of these patients died. Three other patients had emergency surgery one with left ventricular failure and a left ventricular aneurysm and two following cardiac arrests during investigation. Early mortality in the group having emergency surgery was 17.4% overall (Table 8) and 15.8% in those having bypass grafts alone (Table 4).

Symptomatic results, recurrent angina and late mortality

Follow-up details for patients having bypass grafting alone are summarized in Table 9. For geographical reasons a number of patients were unavailable for follow-up but these did not differ significantly in their pre-operative evaluation from those available for regular follow-up. Mean follow-up was approximately 12 months after surgery. Over the follow-up period there is a progressive decline of those symptom-free and symptomatically improved with an increasing incidence of recurrent angina. Of the patients, 74% were symptom-free, and 84.9% improved at 1 year; 70.0% were symptom-free and 80.0% improved at 2 years. The incidence of recurrent angina or deterioration

TABLE 7. Influence of extent of coronary artery disease and number of grafts on hospital mortality for aortocoronary grafting

	Mortality	%
Coronary artery disease (number of vessels with greater than 50% luminal stenosis)		
1	0/38	0
2	2/55	3.6%
3	6/53	11.3%
Two and three vessel coronary artery disease excluding left main coronary artery disease	5/98	5.1%
Left main coronary artery disease (greater than 50% luminal stenosis)	3/10	30%
Number of aortocoronary grafts inserted		
1	0/30	0
2	2/59	3.4%
3 or 4	6/57	10.5%
No endarterectomy	3/85	3.5%
Endarterectomy	5/61	8.2%

TABLE 8. Hospital mortality for emergency aortocoronary bypass grafting

Indication for surgery	Mortality	%
Crescendo angina	0/13	0
Left ventricular failure/aneurysm	0/1	0
Persistent pain or left ventricular failure after recent infarction (within 2 months)	3/7	42.9%
Cardiac arrest during assessment	1/2	50%
Overall	4/23	17.4%

following a period substantially improved was 11.0% at 1 year and 20.0% at 2 years, although in a number of cases the recurrent symptoms were mild compared with pre-operatively. Within this group of patients there have been only two late deaths to date; one 2 months and the other 4 months post-operatively – both sudden, and presumed cardiac, deaths. A single patient has had a further documented myocardial infarction during the follow-up

period with subsequently severe angina requiring reinvestigation. Overall survival at 1 year after surgery was 93.8%.

Reinvestigation

Reinvestigation has been undertaken in nine patients having aortocoronary bypass grafts with recurrent angina following a period symptom-free or much improved after surgery. In this group pre-operatively twenty-seven major arterial segments demonstrated significant coronary artery disease and were considered suitable for bypass grafting. At reinvestigation postoperatively eight of the twenty-seven grafts (30%) were patent. Significant coronary artery disease was demonstrated in three arteries previously free of disease. There was evidence of progression of disease in the native circulation proximal to the grafts in eleven vessels eight of which were completely occluded.

TABLE 9. Follow-up details of patients undergoing aortocoronary bypass grafting. Mean length of follow-up 12.7 months. Total number of patients 146, hospital deaths eight, geographical loss to follow-up 26

	3 months	6 months	12 months	24 months
Number of patients (% follow-up)	112 (99.1%)	100 (99%)	74 (98.6%)	30 (100%)
No symptoms (%)	91 (82.0%)	78 (78.8%)	54 (74.0%)	21 (70.0%)
Improved	12	10	7	1
Unaltered	2	3	3	1
*Symptomatically improved (%)	103 (92.8%)	88 (88.9%)	62 (84.9%)	24 (80.0%)
Recurrent angina (%)	5 (4.5%)	6 (6.1%)	8 (11.0%)	6 (20.0%)
Late infarction (%)	1 (0.9%)	—	—	—
†Late death (%)	1 (0.9%)	2 (2.0%)	1 (1.4%)	1 (3.3%)

* Includes those symptom-free, symptomatically improved and those with minimal recurrent symptoms compared with pre-operatively.

† Cumulative.

Discussion

Aortocoronary bypass grafting was introduced by Favalaro and his associates at the Cleveland Clinic in 1967 (Favaloro, 1968, 1969). Since that time it has become a widely practised treatment for symptomatic coronary artery disease. The merit or otherwise of surgery for asymptomatic coronary artery disease remains to be established. In this series the indication for surgery was, in general, severe symptomatic coronary artery disease refractory to medical therapy. Most patients, particularly those with stable angina pectoris, had an adequate trial of medical treatment with nitrates and β -blocking drugs before consideration of coronary arteriography and coronary artery surgery. Other indications for surgery included patients severely symptomatic with complications of obstructive coronary artery disease and those with valvular disease and significant coronary artery disease. Patients with left main coronary artery disease tended to present earlier and with severe symptoms, however, once this lesion was established arteriographically, surgery was considered the treatment of choice.

The results presented are a comprehensive review of coronary artery surgery in the cardiothoracic unit of a teaching hospital over a 31-month period. The aim of the review was to establish whether such a cardiothoracic unit could achieve comparable results to the previously published reports from larger cardiac centres abroad specializing in coronary artery surgery and to analyse those factors which influence early mortality.

For elective bypass grafting hospital mortality was 3.9% and in eighty-one patients with good pre-operative left ventricular function (ejection fraction greater than 0.55) mortality was 2.5%. Previous reports state hospital mortality for uncomplicated bypass grafting in the range 1.3–12% (Favaloro, 1972; Manley and Johnson, 1972; Reul *et al.*, 1972; Collins *et al.*, 1973; Hall *et al.*, 1973; Sheldon *et al.*, 1973; Cooley *et al.*, 1973; Forker *et al.*, 1974; Cannom *et al.*, 1974; Anderson *et al.*, 1974; Najmi *et al.*, 1974; Balcon *et al.*, 1974; Bennett *et al.*, 1974; Kouchoukos, Kirklin and Oberman, 1974). In the larger series comprising more than 500 cases (Favaloro, 1972; Manley and Johnson, 1972; Reul *et al.*, 1972; Hall *et al.*, 1973; Sheldon *et al.*, 1973; Cooley *et al.*, 1973; Cannom *et al.*, 1974; Bennett *et al.*, 1974; Kouchoukos *et al.*, 1974) hospital mortality ranges from 1.3 to 7.1% with the Cleveland Clinic experience of 4935 bypass graft operations from 1967 to 1973 demonstrating an overall hospital mortality of 1.3% and a progressive decline in hospital mortality over the years with increasing experience and more exacting selection of patients for surgery, particularly the exclusion of

those with severely impaired left ventricular function (Bennett *et al.*, 1974). Two other factors are perhaps of importance. Firstly the proportion of multiple grafts suggesting more diffuse coronary artery disease was 116/146 (79%) in the present series while this proportion is often lower in other series; 2967/4694 (63%) of patients having bypass grafts alone in the Cleveland Clinic series from 1970 to 1973 (Bennett *et al.*, 1974). Secondly, although difficult to establish, the patient who is referred to a surgical group in their early experience is not infrequently the patient with severe functional disability and 'end-stage' disease. Smaller series more directly comparable with the present one demonstrate a hospital mortality for uncomplicated bypass grafting of 6.2% (Forker *et al.*, 1974), 6.4% (Balcon *et al.*, 1974) and 12% (Najmi *et al.*, 1974).

The possible influences on hospital mortality in uncomplicated bypass grafting are considered separately to demonstrate trends although clearly in many instances these risk factors are not independent and act either through increasing extent and severity of coronary artery disease or through deterioration of pre-operative left ventricular function.

Except in the oldest age group (60–69 years) age had no clear influence on hospital mortality; however, mortality was increased in female patients in those suffering from sustained hypertension pre-operatively and particularly in those with diabetes mellitus.

A major influence on hospital mortality was the pre-operative state of the left ventricular myocardium. Mortality was increased from 3.9% in those with normal heart size or slight enlargement on chest X-ray to 5.0% in those with moderate or severe cardiac enlargement. Elevation of left ventricular end-diastolic pressure (>12 mmHg at rest) resulted in a hospital mortality of 14.3% compared to 4% for those with normal left ventricular end-diastolic pressure. In reported series, evidence of congestive cardiac failure resulted in increased hospital mortality from 1.9% to 29% (Kouchoukos *et al.*, 1974) and from 3.9 to 19% (Kaiser *et al.*, 1972) and elevation of left ventricular end-diastolic pressure (>18 mmHg at rest) from 9 to 30% (Kay *et al.*, 1972).

The present results show a progressive increase in hospital mortality with increasing left ventricular dyskinesia whether reflected in the appearance of the left ventricle on ciné-angiograms or in the left ventricular ejection fraction. These trends are noted in other series. Hospital mortality ranged from 5% (normal left ventricle) to 37% (two walls dyskinetic) (Manley and Johnson, 1972) and from 4% (normal) to 27% (two walls dyskinetic) (Forker *et al.*, 1974). A similar trend is seen with respect to left ventricular ejection fraction; when greater than 0.45, hospital

mortality was 3% compared to 31% when less than 0.2 (Kay *et al.*, 1972). In another series when ejection fraction was greater than 0.25, hospital mortality was 4% and 25% when ejection fraction was less than 0.25 (Oldham *et al.*, 1972).

Prior myocardial infarction and the interval between infarction and surgery is a second major influence on hospital mortality. In a study from the Texas Heart Institute (Dawson *et al.*, 1974) reviewing 1700 operations, early mortality in those with no previous infarct was 4.1%, old infarction 6.9% and recent infarction 14.5% (surgery 0–24 hr after infarction 36.4%, 2–7 days after infarction 40%, 7–30 days after infarction 16.4% and 31–60 days after infarction 5.8%). In the present series the trend was similar. In those with no previous infarct mortality was 2.8%, old infarction 5.8% and surgery within 2 months of infarction (three out of five within 24 hr of infarction) 40%. Other series have reported high mortality for surgery for the complications of acute myocardial infarction 54.2% (Buckley *et al.*, 1971) and for surgery following infarction during cardiac catheterization 36% (Reul *et al.*, 1973).

The extent of coronary artery disease showed a clear influence on hospital mortality, this increased from no deaths with single vessel disease to 11.3% with triple vessel disease, and from 5.1% with double or triple vessel disease with a normal left main coronary artery to 30% when there was significant disease of the left main coronary artery. These trends are described in some previous reports; no mortality for single vessel disease and 26.1% mortality for triple vessel disease (Reul *et al.*, 1972); 2.5% mortality for single vessel disease and 14.1% mortality for quadruple vessel disease (Najmi *et al.*, 1974). However, this trend is not demonstrated in other reports (Hall *et al.*, 1973; Kouchoukos *et al.*, 1974). Mortality for surgery in the presence of left main coronary artery disease is consistently high in reported series 8.2% (Pichard *et al.*, 1973), 10.7% (Zeft *et al.*, 1974), 14% (Takaro *et al.*, 1976), 28.4% (Sharma *et al.*, 1973), and 39% (Kisslo *et al.*, 1973).

Emergency surgery carried a higher mortality than elective surgery with a hospital mortality for emergency bypass grafting of 15.8%. This mortality reflects the high risk of surgery in the situation of recent myocardial infarction while, interestingly, there were no deaths in thirteen patients operated on for crescendo angina which had failed to respond to aggressive medical therapy.

The surgical procedure carried out strongly influenced hospital mortality. Mortality increased with the number of bypass grafts inserted from no deaths with single grafts to 10.5% mortality with three or four grafts and concomitant endarterectomy resulted in increased mortality from 3.5 to 8.2%. Resection of left ventricular scars or valve surgery

led to an increase in mortality. In this series the mortality for combined bypass grafting and aneurysm resection was 30.8% (compared with 16.7% for aneurysm resection alone over the same period) and for combined valve surgery and bypass grafting 21.1% – this latter group including patients with primary valve disease and those with mitral dysfunction secondary to poor left ventricular function or papillary muscle damage. The Texas Heart Institute series (Cooley *et al.*, 1973) reviewed 1492 operations, 1289 patients had bypass grafts alone with a mortality of 7.1%, eighty-six patients had combined aneurysm surgery and a mortality of 16.3% and eighty-four patients had combined valve surgery and a mortality of 23.8%. The Baylor series (Reul *et al.*, 1972), reviewing 1287 operations, yielded early mortality figures of 5.2, 18.2 and 28.1% respectively. Deaths at the time of operation occurred with patent grafts, suggesting that the severely compromised myocardium has exacting metabolic requirements and that hypoxia or other metabolic disturbances may rapidly produce an irreversible situation. Patients dying postoperatively commonly had occluded grafts and evidence at post-mortem of recent infarction with the consequences of reduced pump function and predisposition to arrhythmias. Early graft occlusion may be causally related to peri-operative infarction and early death.

Symptomatic results are excellent, 74% of patients having bypass grafts alone were symptom-free at one year after surgery, 85% symptomatically improved. At 2 years after surgery 70% were symptom-free and 80% improved. In reported series with mean length of follow-up between 6 months and 5 years after surgery those symptom-free ranged from 33 to 79% and improved from 60 to 96% with a tendency to deterioration of results with length of follow-up (Manley and Johnson, 1972; Reul *et al.*, 1972; Collins *et al.*, 1973; Hall *et al.*, 1973; Sheldon *et al.*, 1973; Cannom *et al.*, 1974; Anderson *et al.*, 1974; Kouchoukos *et al.*, 1974; Najmi *et al.*, 1974; Balcon *et al.*, 1974; Bennett *et al.*, 1974). Reported graft patency at 6–12 months after surgery is in the range 73–87% (Favaloro, 1972; Manley and Johnson, 1972; Reul *et al.*, 1972; Kaiser *et al.*, 1972; Hall *et al.*, 1973; Sheldon *et al.*, 1973; Anderson *et al.*, 1974; Kouchoukos *et al.*, 1974), and symptomatic results generally correlate well with this. In the present study, reinvestigation was not undertaken routinely but the excellent symptomatic results suggest adequate graft patency rates. A proportion of patients demonstrate recurrent angina or deterioration following a period symptom-free or substantially improved, this proportion increasing with interval following surgery. In this series, 11.0% of patients had recurrent

angina at 1 year after surgery and 20.0% at 2 years. A high proportion of these patients with recurrent angina have been reinvestigated and both progression of disease in the native coronary circulation and occlusion of grafts was common – the latter presumably representing late graft occlusion. There have been only two late deaths in this series during the follow-up period and a single documented late myocardial infarction.

The number of operations performed and the limited period of follow-up do not allow generalizations as to the effects of surgery on longevity. In a large series of patients with angiographically documented coronary artery disease, studied before coronary artery surgery was widely available, the 1-year mortality (according to the number of vessels diseased) was single vessel disease 4%, double vessel disease 12%, triple vessel disease 22% and left main coronary artery disease 30% (Bruschke, Proudfit and Sones, 1973a). The mortality was considerably higher in those with poor left ventricular function (Bruschke *et al.*, 1973b) and overall 1-year survival was 88.5%.

Both medical and surgical therapy have advanced since this early series was concluded and a recently reported study – the Veterans Administration Co-operative Study of surgery for coronary artery occlusive disease – with random allocation of patients to medical and surgical therapy reveals an early surgical mortality of 5.6% and 1-year survival rates for surgery of 93% and for medical therapy of 95% (Murphy *et al.*, 1977; Detre, Hultgren and Takaro, 1977). This excludes a subgroup with left main coronary artery disease in whom early surgical mortality was 14% and 1-year survival rates for surgery and medical therapy were 85 and 71% respectively (Takaro *et al.*, 1976). In the present series of patients, most of whom were severely symptomatic and had not responded to adequate medical therapy, overall hospital mortality for elective grafting was 3.9% and 1-year survival 93.8%.

The overall results from a British teaching hospital with a relatively small experience thus compare favourably with results from the much larger series from the United States. The increased mortality from operation in the presence of impaired left ventricular function, diabetes, hypertension and recent infarction should be noted and quantitated when selecting patients disabled by angina for a successful pain-relieving procedure.

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