

# Results of aortocoronary bypass operations

## *Follow-up in 343 patients*

R. M. DONALDSON<sup>1</sup>, M. HONEY, M. F. STURRIDGE, J. E. C. WRIGHT,  
AND R. BALCON

*From The London Chest Hospital, London*

**SUMMARY** Three hundred and forty-three patients who had aortocoronary bypass graft operations for disabling angina were followed up for from 6 months to 5 years (average 2 years). 80 per cent had multiple grafts and 20 per cent had additional endarterectomy. The overall mortality within one month of operation was 5 per cent, and in those who had vein graft procedures only was 4 per cent. 11 per cent had a postoperative myocardial infarction (6% perioperative) and there were 3 per cent late deaths. At 3 years 90 per cent are surviving. 80 per cent are asymptomatic without treatment. The mean angina grade was 0.3 at the latest follow-up, compared with 2.5 before operation; maximum exercise tolerance was also significantly improved ( $P < 0.001$ ). When angina recurred, it did so in 80 per cent of the cases within 12 months of operation and was usually attributable to inadequate revascularisation. Ventricular function as assessed by preoperative ventriculography was the factor most clearly related to survival rate and the early excellent results of coronary bypass operations seem to be maintained up to 5 years. It is, therefore, reasonable to continue to advise operation if only for relief of angina.

The early excellent clinical results achieved in many centres by aortocoronary bypass grafting has encouraged cardiologists to recommend this operation for symptomatic relief of angina. The continued use of the procedure will depend to a large extent on the late results. In this report we examine our experience with 343 patients followed up for from 6 months to 5 years after operation.

### **Preoperative assessment**

Patients presenting with angina pectoris from February 1971 to February 1976 were considered for surgical treatment and admitted to hospital for evaluation. The preoperative assessment and operative procedure have been described previously (Balcon *et al.*, 1974). Because of chest pain, 893 patients were investigated angiographically. This excludes those that had associated valvar disease or non-coronary myocardial pathies. There were 343 patients who were referred for an aortocoronary

bypass graft operation, and 304 of these were men and 39 women, with ages ranging from 19 to 71 years (median 50). Seventy-five per cent (75%) of the patients were between 40 and 60 years of age.

Angina was graded from 1 to 4 using the same criteria as the New York Heart Association grading for dyspnoea. The average angina grade was 2.5; the duration of angina ranged from 1 week to 19 years and averaged 20 months. Ninety-six (28%) had exertional dyspnoea as a limiting symptom in addition to angina and in those patients the mean dyspnoea grade was 2.1. Ninety per cent (90%) of the patients had been treated with sublingual glyceryl trinitrate and 85 per cent with beta-adrenergic blocking agents. Of the patients 240 (70%) had abnormal resting electrocardiograms and 50 per cent had electrocardiographic evidence of at least one previous myocardial infarction.

The patients usually performed a standardised exercise test in the upright position on a bicycle ergometer with recording of a bipolar chest lead, starting at 24.5 Watts (150 kpm/m) and increasing by increments of 24.5 Watts (150 kpm/m) every 2 minutes until forced to stop by the development of angina, 2 mm ST segment depression on the electrocardiogram, dyspnoea, or fatigue. Two

<sup>1</sup>Present address: Department of Cardiology, The Middlesex Hospital, London W1N 8AA.

hundred and seventy-seven patients had an exercise test before and after operation; the maximum work load preoperatively ranged from 24.5 Watts (150 kpm/m) to 171.7 Watts (1050 kpm/m), with an average of 85.8 Watts (525 kpm/m).

Left and right heart catheterisation was performed from the right arm after premedication with 20 to 25 mg of intramuscular diazepam. Left ventriculography was performed in the right anterior oblique projection and followed by selective coronary angiography in multiple projections, preferably using the Sones technique. A caesium iodide image intensifier was used and 35 mm cine film was exposed at 35 frames per second. The angiographic severity of coronary artery disease was represented by a numerical score. Each major vessel was scored on a scale of 0 to 4; 0 was normal, 4 total occlusion, and 1 to 3, stenosis of increasing severity. Patients selected for bypass surgery were those who had angiographic demonstration of major (grade 3 or 4) lesions obstructing one or more of the main coronary arterial branches and who continued to have angina, interfering with their normal activities in spite of treatment with glyceryl trinitrate and beta-adrenergic blocking agents. Fifty-five (16%) patients had major lesions (score 3 or 4) of a single vessel, 127 (37%) of 2, and 161 (47%) of 3 vessels. Nineteen (6%) had a major lesion (i.e. grade 3 or 4) of the left main coronary artery.

The systolic movement of the myocardium was analysed in each of 3 segments (anterior, apical, and posteroinferior) of the outline of the left ventricle on the ventriculogram, and was classed either as normal or as showing akinetic or dyskinetic (paradoxical) wall motion (Herman and Gorlin, 1969). Areas of reduced wall movement (hypokinesis), which often improved after sublingual glyceryl trinitrate, were classified as normal. Thus the 'normal' group included some patients with reduced ejection fraction. Those with severe left ventricular dysfunction (i.e. 3 hypokinetic segments and greatly reduced ejection fraction) were excluded. The left ventriculogram was 'normal' in 246 patients (72%); 64 (19%) had 1 akinetic or dyskinetic segment; and 33 (10%) had 2 or more abnormally contracting segments on ventriculography.

### Operative procedure

Operation was usually performed within one month of investigation. After removal of a length of saphenous vein, the coronary anastomoses were performed under normothermic cardiopulmonary bypass with intermittent aortic cross-clamping. During the past 3 years, endarterectomy has been done before graft insertion in some patients; others had

additional procedures related to their coronary artery disease. One-fifth of the patients had grafts to a single vessel only. The remainder had multiple graft operations (44% double grafts, 31% triple, and 6% quadruple grafts). A prior endarterectomy was necessary to render a vessel suitable for grafting in 20 per cent of the patients. In 29 patients (9%) bypass grafting was combined with other procedures, viz. left ventricular aneurysmectomy in 18 (5%), closure of ventricular septal defect in 6 (2%), and mitral annuloplasty in 5 (2%). Most patients were discharged from hospital by the end of the second week and anticoagulant treatment was continued for at least 3 months after operation.

The mortality within one month of operation was 5 per cent (18 patients) but for those who underwent an uncomplicated bypass graft procedure only this figure was 4 per cent (13 patients). Eleven patients died in hospital: 4 from pulmonary embolism (3 of these before routine postoperative anticoagulant treatment was used), 1 from haemorrhage, 2 from respiratory complications, 1 from unheralded ventricular fibrillation, and 3 who could not be weaned from cardiopulmonary bypass from myocardial failure.

The diagnosis of perioperative myocardial infarction was based on electrocardiographic evidence: the appearance of new Q waves, bundle-branch block, or loss of R wave progression in praecordial leads. This was documented in 20 patients (6%).

### Analysis of data

Data were recorded on mark-sense cards, stored, and then analysed on a CDC 6400 computer. Life table analysis was performed to determine the survival rates, and differences in survival rate between subgroups were tested for statistical significance using the chi-square test ( $\chi^2$ ).

### Postoperative follow-up

Patients were seen at 6-monthly intervals after operation, usually at a special follow-up clinic, where the occurrence of dyspnoea, angina, or myocardial infarction, and results of exercise testing were documented. In some patients this information was obtained from the referring physician. Of the 325 survivors of operation, 315 (97%) were included in the follow-up, which ranged from 6 months to 5 years, with an average of 2 years. Ten (3%) of the patients were either untraceable or overseas and lost to follow-up.

There were 11 late deaths (3% of all cases) from cardiac causes, including 5 that were sudden (overall mortality 8%). Fifteen patients (5%) have had

a documented late myocardial infarction and 5 of these patients died. Two hundred and sixty-one patients (80%) had no further angina after operation and required no antianginal treatment. In a further 18 (6%) angina was improved by at least two clinical grades; 38 (12%) were either unchanged or worse after operation. The average grade of angina has fallen from 2.5 to 0.3 ( $P < 0.001$ ). When angina reappeared after operation, it did so in 48 (86%) of the 56 patients within 12 months of operation and only 8 (3%) of all survivors had late recurrence of angina (2 or more years after operation). In the 277 patients who performed bicycle ergometer tests before and after operation, the exercise tolerance was significantly greater in the postoperative tests [from average of 85.8 Watts (525 kpm/m) to 106 Watts (648 kpm/m)] ( $P < 0.001$ ) and angina was the limiting factor in only 69 patients (25%). Of our patients 125 (36%) have been reinvestigated by coronary arteriography and in these 79 per cent of the 243 grafts were patent at an average of 14 months after operation.

The overall 3-year survival rate was 90.4 per cent. There was a significant difference between the survival of the patients with normal left ventricular function and that of the group with impaired ventricular contractility. Of the former 80 per cent survived 3 years, compared with a 63 per cent and 35 per cent survival for those with one and two (or more) akinetic or dyskinetic segments, respectively (Fig.).

## Discussion

The reported hospital mortality in large series for bypass grafting alone varies from 0.7 per cent

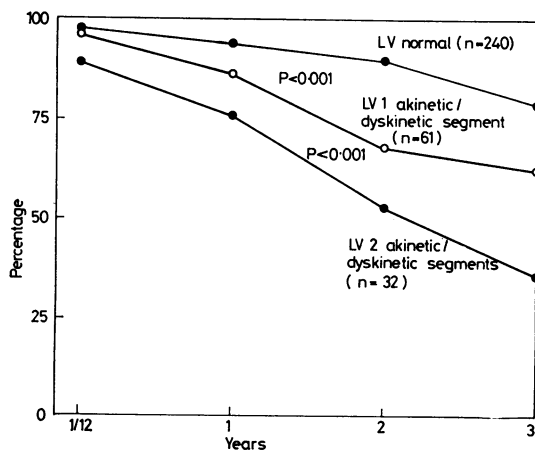


Fig. Postoperative survival curves for individual ventriculographic categories.

(Ullyot *et al.*, 1975) to 7 per cent (Anderson *et al.*, 1974). Our figure of 4 per cent is comparable. The excellent symptomatic relief that follows bypass graft surgery had been previously documented and clinical improvement can be expected in 80 to 90 per cent of the patients. The presence of disabling symptoms constituted the prime indication for operation in our cases and 80 per cent of the patients who survived operation are currently asymptomatic without drug treatment. Similar results have been obtained by others (Manley and Johnson, 1972; Kouchoukos *et al.*, 1974; Ross, 1975; Sheldon *et al.*, 1975). In our patients bypass graft surgery was also evaluated by exercise testing, which showed a significant improvement in maximal work capacity, as in other comparable series (Amsterdam *et al.*, 1970; Lapin *et al.*, 1973). This has also been shown by Siegel *et al.* (1974) in patients in whom only partial myocardial revascularisation was achieved. Perhaps more important, stress induced angina occurred significantly less often in the postoperative exercise test. The considerable symptomatic improvement was maintained throughout the 5-year follow-up period, as in the large group of patients reported from the Cleveland Clinic by Sheldon *et al.* (1975).

When angina recurred, it did so in 86 per cent of 56 cases within 12 months of operation during the time when graft occlusion is also most likely to occur (Flemma *et al.*, 1972). Most clinical studies have shown a close correlation between bypass graft patency and good symptomatic result (Adam *et al.*, 1972; Manley and Johnson, 1972). We also have observed that early reappearance of symptoms was associated with non-functioning grafts or inadequate revascularisation (Banim and Balcon, 1976). The proportion of patients receiving multiple grafts has increased since our last report (Balcon *et al.*, 1974) from 56 to 80 per cent, and it is our current view that revascularisation should be as complete as possible, as this appears to be the most important factor in determining the degree of symptomatic improvement. Endarterectomy was done in 20 per cent of the patients in addition to bypass grafting to achieve maximal revascularisation; as we have found that this does not adversely affect the clinical result, we now do this wherever necessary (Banim *et al.*, 1976). Bypass grafting can be safely combined with aneurysmectomy in the treatment of post-infarction ventricular aneurysms (Donaldson *et al.*, 1976). All but 1 of the 18 patients in this series who underwent the combined procedure had excellent symptomatic relief.

Postoperative transmural infarction diagnosed by electrocardiographic criteria has been reported to occur in between 1.2 per cent (Cannon *et al.*, 1974)

and 20 per cent (Brewer *et al.*, 1973). The 6 per cent perioperative infarction rate in our group is similar to that reported by Sheldon *et al.* (1975). Detailed analysis of wall motion abnormalities suggests that these figures may underestimate the true incidence (Rickards *et al.*, 1977). Fifteen patients had myocardial infarction during the follow-up period; all had recurrent angina before this occurred.

It seems unlikely that perioperative infarction alone can account for all the symptomatic improvement seen after operation, since this occurred in only a small proportion of those who improved. It has also been suggested that the relief of pain can be attributed to denervation of the ischaemic zone (Soloff, 1973) or to a non-specific effect of surgery (Diamond *et al.*, 1960). However, the close correlation between graft patency and clinical benefit suggests that these mechanisms are unlikely to be responsible for the improvement which follows operation in more than a small proportion of patients.

Two-year survival for our group was 93 per cent and is similar to that reported from large surgical centres which ranges from 85 per cent (McNeer *et al.*, 1974) to 94 per cent (Sheldon *et al.*, 1975). Left ventricular function as estimated by pre-operative ventriculography appears to be an important determinant of prognosis in patients treated medically (Oberman *et al.*, 1972; Brusckhe *et al.*, 1973; Burggraaf and Parker, 1975). Of our patients, 28 per cent had one or more akinetic or dyskinetic segments on the ventriculogram, and we have found that ventricular function assessed in this way was also the most important predictor of survival after operation; Sheldon *et al.* (1975) have made a similar observation. The extent of myocardial damage was most probably underestimated in our group of patients as 70 per cent of the patients had abnormal resting electrocardiograms and 50 per cent had at least one previous myocardial infarction; furthermore, lesser abnormalities (hypokinesia) in segmental myocardial contractility were not taken into consideration.

Our experience shows that the excellent early results of aortocoronary bypass operation are maintained over a period of up to 5 years; it is, therefore, reasonable to continue to advise operation if only for relief of angina without taking into consideration any improved prospects of survival which may have resulted.

## References

Adam, M., Mitchel, B. F., Lambert, C. J., and Geisler, G. F. (1972). Long-term results with aorta-to-coronary artery bypass vein grafts. *Annals of Thoracic Surgery*, **14**, 1-9.

- Amsterdam, E. A., Iben, A., Hurley, E. J., Zelis, R., Spann, J. F., Jr., and Mason, D. T. (1970). Physiological assessment of coronary vein bypass graft in refractory angina pectoris. Clinical demonstration of improved blood flow to ischemic myocardium (abstract). *Circulation*, **41** and **42**, Suppl. III 129.
- Anderson, R. P., Rahimtoola, S. H., Bonchek, L. I., and Starr, A. (1974). The prognosis of patients with coronary artery disease after coronary bypass operations. *Circulation*, **50**, 274-282.
- Balcon, R., Honey, M., Rickards, A. F., Sturridge, M. F., Walsh, W., Wilkinson, R. K., and Wright, J. E. (1974). Evaluation by exercise testing and atrial pacing of results of aorto-coronary bypass surgery. *British Heart Journal*, **36**, 841-853.
- Banim, S. O., and Balcon, R. (1976). Analysis of preoperative and operative factors influencing outcome of aortocoronary bypass surgery in 146 patients (abstract). *British Heart Journal*, **38**, 532.
- Banim, S. O., Wright, J. E. C., and Balcon, R. (1976). The effect of endarterectomy on the results of aortocoronary bypass surgery (abstract). In *Proceedings of Seventh European Congress of Cardiology*, **1**, 294.
- Brewer, D. L., Bilbro, R. H., and Bartel, A. C. (1973). Myocardial infarction as a complication of coronary bypass surgery. *Circulation*, **47**, 58-64.
- Brusckhe, A. V. G., Proudfit, W. L., and Sones, F. M., Jr. (1973). Progress study of 590 consecutive nonsurgical cases of coronary disease followed 5-9 years. II. Ventriculographic and other correlations. *Circulation*, **47**, 1154-1163.
- Burggraaf, G. W., and Parker, J. O. (1975). Prognosis in coronary artery disease. Angiographic, haemodynamic and clinical factors. *Circulation*, **51**, 146-156.
- Cannon, D. S., Miller, C., Shumway, N. E., Fogarty, T. J., Daily, P. O., Hu, M., Brown B., Jr., and Harrison, D. C. (1974). The long-term follow-up of patients undergoing saphenous vein bypass surgery. *Circulation*, **49**, 77-85.
- Diamond, E. G., Kittle, C. F., and Crockett, J. E. (1960). Comparison of internal mammary artery ligation and sham operation for angina pectoris. *American Journal of Cardiology*, **5**, 483-486.
- Donaldson, R. M., Honey, M., Balcon, R., Banim, S. O., Sturridge, M. F., and Wright, J. E. C. (1976). Surgical treatment of postinfarction left ventricular aneurysm in 32 patients. *British Heart Journal*, **38**, 1223-1228.
- Fleming, R. J., Johnson, W. D., Lepley, D., Jr., Tector, A. J., Walker, J., Gale, H., Beddingfield, G., and Manley, J. C. (1972). Late results of saphenous vein bypass grafting for myocardial revascularization. *Annals of Thoracic Surgery*, **14**, 232-242.
- Herman, M. V., and Gorlin, R. (1969). Implication of left ventricular asynergy. *American Journal of Cardiology*, **23**, 538-547.
- Kouchoukos, N. T., Kirklin, J. W., and Oberman, A. (1974). An appraisal of coronary bypass grafting. *Circulation*, **50**, 11-16.
- Lapin, E. S., Murray, J. A., Bruce, R. A., and Winterscheid, L. (1973). Changes in maximal exercise performance in the evaluation of saphenous vein bypass surgery. *Circulation*, **47**, 1164-1173.
- McNeer, J. F., Starmer, C. F., Bartel, A. G., Behar, V. S., Kong, Y., Peter, R. W., and Rosati, R. A. (1974). Nature of treatment selection in coronary artery disease. *Circulation*, **49**, 606-614.
- Manley, J. C., and Johnson, W. D. (1972). Effects of surgery on angina (pre- and post-infarction) and myocardial function (failure). *Circulation*, **46**, 1208-1221.
- Oberman, A., Jones, W. B., Riley, C. P., Reeves, T. J., Sheffield, L. T., and Turner, M. E. (1972). Natural history of coronary artery disease. *Bulletin of the New York Academy*

- of Medicine*, **48**, 1109-1125.
- Rickards, A. F., Seabra-Gomes, R., Balcon, R., Donaldson, R. M., and Wright, J. (1977). Assessment of myocardial damage following coronary surgery (abstract). *British Heart Journal*, **39**, 929.
- Ross, R. S. (1975). Ischemic heart disease: an overview. *American Journal of Cardiology*, **36**, 496-505.
- Sheldon, W. C., Rincon, G., Pichard, A. D., Razavi, M., Cheanvechai, C., and Loop, F. D. (1975). Surgical treatment of coronary artery disease: pure graft operations, with a study of 741 patients followed 3 to 7 years. *Progress in Cardiovascular Diseases*, **18**, 237-253.
- Siegel, W., Lim, J. S., Proudfit, W. L., Sheldon, W. C., and Loop, F. D. (1974). Exercise test and angiographic correlations in myocardial revascularization surgery (abstract). *Circulation*, **49** and **50**, Suppl. III, 132.
- Soloff, L. A. (1973). Effects of coronary bypass procedure. *New England Journal of Medicine*, **288**, 1302-1303.
- Ullyot, D. J., Wisneski, J., Sullivan, R. W., and Gertz, E. W. (1975). Improved survival after coronary artery surgery in patients with extensive coronary artery disease. *Journal of Thoracic and Cardiovascular Surgery*, **70**, 405-413.

Requests for reprints to Dr R. M. Donaldson, The Middlesex Hospital, Mortimer Street, London W1N 8AA.