Surgery for hibernation
J Pepper

In the early 1980s Rahimtoola reviewed the results of coronary bypass surgery trials and identified patients with coronary artery disease and chronic left ventricular dysfunction that improved upon revascularisation. The results of medical treatment for ischaemic cardiomyopathy have been poor. Coronary artery bypass grafting provides superior long term survival, but may be associated with a high operative mortality and significant morbidity for certain patient subgroups with heart failure and very low left ventricular ejection fraction (LVEF). The potential benefits of revascularisation are to reduce the ischaemic burden, to reduce the arrhythmic potential, to reduce maladaptive growth, and to restore the coordinated movement in dysfunctional myocardial segments.

Data from the coronary artery surgery study (CASS) registry for patients with LVEF < 35% involved 651 patients. The five year survival was significantly better in surgical patients (68%) than in the medical group (54%). The contrast became more pronounced in patients with LVEF < 26% whose five year survival was 63% with surgery, but 43% with medical treatment. This information is the cornerstone of our current approach to patients with coronary artery disease and heart failure. The difficulties in selecting patients and in interpreting both metabolic and functional scans, particularly when they are discordant, will be discussed.

PREOPERATIVE ASSESSMENT
Case selection is arguably the most important ingredient for success in coronary artery surgery for ischaemic cardiomyopathy. We commonly perform both extended thallium perfusion scans to assess coronary flow and dobutamine stress echocardiography to assess function. When both modalities are in agreement either negative or positive, the clinical decision is straightforward. Unfortunately, in approximately 20–45% of cases the tests disagree and the results of coronary artery bypass grafting in this setting are, not surprisingly, unpredictable.

A common clinical problem is to establish the relevance of coronary stenoses in the presence of hypertensive, viral, or alcoholic induced cardiomyopathy. Assessment of contractile and metabolic function at rest and on exercise can be very helpful. Other important issues are the assessment of co-existing mitral regurgitation, ventricular arrhythmias, and renal impairment. In general, a preoperative creatinine clearance < 50 ml/min is associated with a 50% chance of the need for haemofiltration in the early postoperative course. Right heart catheterisation is an essential prerequisite in these patients in order to assess right ventricular function and to measure pulmonary artery pressure. A mean pulmonary artery pressure of 40 mm Hg or greater is a contraindication to this kind of surgery.

Hibernation is a functional state of the myocardium, which can progress to an irreversible state if left too long. This may be due to remodelling of small intramyocardial arteries, resulting in narrowing and reduced flow within the segment of hibernating myocardium. This was brought out in a study by Schwarz and colleagues who showed in 32 patients with a mean (SD) preoperative LVEF of 540 (14)%, that post-operative recovery of function was enhanced in patients with a short history of hibernation compared with patients with a chronic condition (LVEF 60 (10)% vs 47 (14)%; p < 0.05).

PREOPERATIVE TREATMENT
We have a low threshold for the use of the intra-aortic balloon pump (IABP) for patients on maximal medical treatment or who have severe left main stem stenosis with or without critical right coronary artery stenosis. Dietl and colleagues undertook a five year retrospective study of 163 consecutive patients with impaired left ventricular function (LVEF < 25%) who had undergone coronary artery bypass surgery (CABG). Thirty seven patients received IABP support preoperatively, but 126 did not. The 30 day mortality was 2.7% among patients receiving preoperative IABP versus 11.9% in the non-preoperative IABP group (p < 0.005).

These patients are invariably receiving angiotensin converting enzyme or AT1 inhibitors, which we continue up to the induction of anaesthesia. As a consequence, it is commonplace for α agonists to be required during cardiopulmonary bypass to maintain a mean perfusion pressure above 60 mm Hg.

OPERATION
With recent improvements in anaesthesia, myocardial management, and completeness of revascularisation, the operative mortality has been reduced to below 10% in most series. Perioperative care has been enhanced by the increased use of IABP and short term ventricular assist devices.

Some clinical series restrict their patient population to only those undergoing isolated coronary artery bypass, while others include patients that undergo concomitant procedures, such as left ventricular aneurysm repair, or implantable defribillator implantation. Other variables include the prevalence and degree of angina or heart failure. Some studies report exclusively on patients undergoing primary CABG, while others include those undergoing redo operations.

Operative mortality in these series ranged from 1.8–14.3%. In the study by Langenburg and colleagues there were eight early fatalities (8%) due to refractory ventricular arrhythmias in five patients, low cardiac output in two, and stroke in one. Univariate predictors of early mortality were older age (p < 0.05) and poor target vessel quality (p < 0.05).

LATE MORTALITY
Late deaths following revascularisation in patients with ischaemic cardiomyopathy are due most commonly to ventricular arrhythmias, progressive heart failure, and co-morbid conditions. The potential benefits of revascularisation are to reduce the ischaemic burden, to reduce the arrhythmic potential, to reduce maladaptive growth, and to restore the coordinated movement in dysfunctional myocardial segments.

Abbreviations: CABG, coronary artery bypass graft surgery; CASS, coronary artery surgery study; IABP, intra-aortic balloon pump; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association; WMS, wall motion score
disease. In the study by Mickleborough, there were 19 late deaths in the 76 operative survivors (25%) with a mean (SD) follow up of 44 (34) months. On multivariate analysis, age over 70 was the only risk factor for late death. Interestingly, the severity of heart failure and the presence of preoperative ventricular arrhythmias did not influence late mortality. Lorusso and colleagues have reported results out to eight years; there were 15 (12.5%) late deaths, mainly from heart failure leading to an actuarial survival of 80 (6)% and 60 (9)% at five and eight years, respectively.

**LEFT VENTRICULAR FUNCTION**

Care is required when evaluating the results of studies assessing changes in left ventricular function, because hibernating myocardium may take several months to recover function. Ghods assessed the time related changes in ventricular function after CABG. Gated pool imaging was used to measure the LVEF early (six days) and late (62 days) after surgery in patients with normal preoperative LV function and those with preoperative LV dysfunction. There were no changes in the clinical status between the early and late studies. Those with normal preoperative LV function showed no significant change. In those with impaired function preoperatively, the LVEF rose from 26 (8)% to 30 (10)% early postoperatively and 34 (8)% late postoperatively (p < 0.05). Patients who showed early improvement continued to do so in the late study. A further seven patients showed improvement only in the late study. The timing of LVEF measurement after surgery is important in patients with left ventricular dysfunction. Early assessment may underestimate the degree of recovery.

With careful case selection, most patients observe improvement in their functional status after operation. Mickleborough reported an improvement in angina class from 3.2 preoperatively to 1.5 postoperatively, with 84% of patients improving by at least one functional class. In the report by Haussman, 52% of patients were in New York Heart Association (NYHA) functional class III or IV preoperatively, whereas only 10% were in this class postoperatively. Christenson, reported on changes in NYHA class in a subgroup of 22 patients that had preoperative pulmonary hypertension, defined as a systolic pulmonary artery pressure of at least 40 mm Hg. In this subgroup, mean NYHA class improved from 3.6 (0.5) to 2.1 (0.8) (p < 0.001).

In a study of 47 patients with coronary artery disease and chronic LV dysfunction, Fath-Ordoubadi and colleagues sought to find out whether the severity of LV dysfunction affected the outcome after coronary artery bypass grafting. Their patients were divided into two groups: group 1 (n = 26) had an EF < 30% and group 2 (n = 21) had an EF > 30%. After coronary bypass surgery, the EF (22 (6)% v 31 (10)%; p < 0.0001) and global wall motion score (WMS) (2.05 (0.39) v 1.56 (0.34); p < 0.001) improved in group 1, whereas the EF (43 (9)% v 43 (12%); p = NS) was unchanged in group 2, although WMS (ended to improve (1.42 (0.38) v 1.32 (0.39); p = 0.09). Revascularisation has the potential for greatest benefit in patients with the most severe dysfunction, but with evidence of viability.

**CONCLUSION**

Coronary artery surgery is an important form of treatment for patients with ischaemic cardiomyopathy, including those for whom angina is a minor component of their symptoms. The option of transplantation is often not adopted because of age, limited availability of donor organs, elevated pulmonary vascular resistance, or co-existing disease such as diabetes, renal impairment, previous malignancy, or chronic airways disease. The accurate assessment of preoperative myocardial viability is a crucial determinant of outcome. In most patients with chronic ischaemic dysfunction, there will be a mixture of some necrotic and fibrotic tissue. In this difficult and controversial area there is a need for a randomised trial.

Correspondence to: Professor J R Pepper, Department of Surgery, Royal Brompton Hospital, Sydney Street, London SW3 6NP, UK; j.pepper@rbh.nthames.nhs.uk

**REFERENCES**


