EDITORIAL

Protecting the damaged heart during coronary surgery

D J Wheatley

Heart 2003;**89**:367–368

In coronary surgery, protective strategies that offer adequate safety for patients with healthy ventricles may not be adequate for those with severe impairment of ventricular function

In this issue of *Heart* Antunes and colleagues,[1] in reporting excellent outcomes for coronary surgery in patients with advanced left ventricular dysfunction, highlight a source of continued controversy concerning the best way of protecting the heart in these circumstances. What has heightened current interest, and prompted reassessment of existing techniques, is the advent of beating heart surgery[2] to add to available strategies for conducting the operation in those whose myocardium has been severely damaged by the effects of coronary disease.

The value of revascularisation in those with impaired left ventricular function is well established.[3] However, when non-working "hibernating" myocardium or fibrous tissue has replaced much contractile myocardium, there are reduced reserves for coping with the injury that so often accompanies coronary surgery. Thus, protective strategies that offer adequate safety for patients with healthy ventricles may not be adequate for those with severe impairment of ventricular function, leading to postoperative low output syndrome and high mortality.

Although there may be a perception that surgeons are operating on older and sicker coronary patients than before, data from the National adult cardiac surgical database[4] indicate that the proportion of surgical patients in the UK with poor left ventricular function (defined, as in the Antunes paper, as an ejection fraction below 30%) remained fairly constant at about 7% over the period 1993 to 1999 inclusive. Illustrating the problem, however, is the fact that the crude hospital mortality for this group over the period was 9.8%, compared with 1.8% for those with good left ventricular function (ejection fraction over 49%).

MYOCARDIAL INJURY DURING SURGERY

There are many sources of myocardial injury during coronary surgery. Ischaemic injury is a risk inherent with any technique which relies on interruption of global coronary perfusion to provide the immobile, bloodless field required for constructing accurate anastomoses between coronary arteries and bypass conduits. The inflammatory response to cardiopulmonary bypass is another source of visceral injury (including myocardial injury) inherent in the standard techniques of surgery using extracorporeal circulation. Overdistention, retraction, athero-embolism, inadequate coronary perfusion, and excessive work demands in the perioperative period are other sources of injury. Generally, these latter influences are well understood and are minimised by intraoperative cardiac decompression, appropriate care in handling and retracting the heart and aorta, as well as careful monitoring and manipulation of heart rate, filling pressure, and systemic vascular resistance.

The attraction to the surgeon of immobile, bloodless coronary arteries obtained with cardiopulmonary bypass and aortic cross-clamping is obvious. Numerous cardioplegic techniques have evolved to protect the myocardium from the effects of global ischaemia during the insertion of bypass grafts. Broadly, these are varieties of crystalloid solutions, or blood with various additives, designed to induce and maintain safe cardiac arrest.

The success of crystalloid cardioplegia and myocardial hypothermia in protecting against prolonged ischaemia is evident from practice in cardiac transplantation. Prompt arrest, rapid global cooling, absence of collateral flow, and cold storage environment allow donor hearts to function well after ischaemic periods of four hours or more. The diseased heart, retained in the body, is a different problem. Administering uniform cardioplegia to a heart with obstructed coronary arteries can be difficult. Retrograde cardioplegic infusion through the coronary sinus may overcome maldistribution problems of antegrade cardioplegia, but washout by collateral flow, and rewarming from adjacent viscera and operating environment remain as problems.

CARDIOPLEGIA

Blood based cardioplegia has become increasingly popular, particularly for the impaired left ventricle. Myocardial cooling, with or without systemic hypothermia, is a frequent adjunct. The combination of absence of external myocardial work and lowered metabolic requirement for essential cell metabolism, induced by cold cardioplegic arrest techniques, allows reasonably safe interruption of global coronary flow for well over an hour—sufficient time for constructing coronary bypasses. Numerous techniques have been described, entailing variations in the composition of cardioplegic solutions, their route and frequency of delivery, and desired myocardial and systemic temperature. Experience of the Emory Clinic[5] is representative of practice; a hospital mortality of 3.8% following coronary surgery for patients with ejection fraction less than 25% is reported (compared to 1.6% for those with ejection fraction over 50%). This group changed from intermittent oxygenated cold crystalloid cardioplegia to blood cardioplegia during the 15 year

Correspondence to: Professor David H Wheatley, Department of Cardiac Surgery, University of Glasgow at Royal Infirmary, 10 Alexandra Parade, Glasgow G31 2ER, UK; d.j.wheatley@clinmed.gla.ac.uk

period under review. Highlighting one aspect of the technique, the Toronto Hospital group[6] reports hospital mortality of 4% in 125 coronary patients with ejection fraction less than 20% using cardiopulmonary bypass and myocardial temperature mapping to guide cardioplegia administration. This low mortality (as well as lower incidence of low output syndrome, perioperative myocardial infarction, and intra-aortic balloon use) is attributed to temperature mapping, as 125 control patients who did not have temperature mapping had a mortality of 11% and higher morbidity.

Buckberg's group has been at the forefront of evolving techniques for replenishing metabolic reserves in the non-working heart after blood cardioplegic arrest, and excellent results have been reported in patients with severely compromised left ventricles, using the principles promulgated by Buckberg.[7] The report from Cimochowski and colleagues[8] illustrates the complexity of protocols for cardioplegic management of the impaired left ventricle. This group reported an operative mortality rate of 1.8% in 111 patients with ejection fraction ranging from 10–34% (mean 27.9%) having coronary surgery with cardiopulmonary bypass and blood cardioplegia, including methylprednisolone, triiodothyronine, glucose, insulin, potassium, aspartate/glutamate, with antegrade and retrograde delivery, together with intra-aortic balloon pumping, inotropic support, and ultrafiltration.

In view of the risk of global ischaemia and the complexity of cardioplegic techniques, there is considerable logic in leaving the heart perfused. Induced ventricular fibrillation provides immobility and a bloodless operating field is achieved by local occlusion of one target artery at a time. Thus only 10–15 minutes, at most, of regional ischaemia is incurred for each distal target. With the reduction in cardiac work achieved by cardiopulmonary bypass and the potential for collateral flow in the decompressed heart, the effect of this ischaemia is further minimised. This is essentially the technique reported, with good outcomes, by the Antunes group.[1]

A variation on this strategy is that of inducing ventricular fibrillation and obtaining a bloodless operating field by cross-clamping the aorta for long enough to construct one distal anastomosis. The aorta is unclamped to allow global myocardial perfusion while the proximal conduit to aorta anastomosis is performed. In this way a number of relatively brief ischaemic periods, interspersed with periods of reperfusion, are used to complete the operation. Thus Bonchek's group,[9] using ventricular fibrillation and intermittent aortic cross-clamping, have reported a hospital mortality of 6.2% in 290 patients with ejection fraction below 30% (compared to 0.7% in 1321 patients with ejection fraction over 50%).

BEATING HEART SURGERY

Dispensing with the extracorporeal circuit avoids the injury of cardiopulmonary bypass, but requires the heart to maintain adequate cardiac output during the construction of distal coronary anastomoses. Beating heart, or "off-pump" surgery has been made easier by the advent of a variety of stabilising and immobilising devices which allow the heart to be displaced or rotated to display the distal target artery, and at the same time provide local immobility. Blood flow through the coronary artery is controlled by external slings, atraumatic clamps, or internal occluders, often incorporating a small lumen to give an intracoronary shunt that maintains distal perfusion while the artery is opened. As experience is being accrued, more and more patients are being operated on with this technique. Currently, it is estimated that about 25% of coronary bypass surgery in the USA is undertaken in this fashion.[10]

Off-pump coronary surgery has been reported to have significant benefits over conventional surgery with cardiopulmonary bypass, particularly in regard to lower bleeding complications and transfusion requirements, and there is a perception of increased safety for those with impaired ventricular function.[10] The difficulties of conducting randomised trials for assessment of beating heart surgery are considerable and have resulted in alternative, and more practical, methods of comparison of propensity matched pairs.[11] Using this technique the Cleveland Clinic group[11] has shown that off-pump coronary surgery is associated with lower morbidity, but more incomplete revascularisation, than conventional coronary surgery, though mortality was similar with both techniques. Shennib and colleagues[2] have compared their results for coronary surgery by the two techniques in patients with ejection fraction of 35% or less. Numbers of patients were small; the reported mortality advantage for beating heart technique (3.2% *v* 10.9%) did not reach significance, though fewer grafts were inserted in the beating heart patients.

Thus, the optimal surgical strategy for patients with severely impaired left ventricular function remains unclear. Given the complexity of diagnosis (ejection fraction alone is inadequate), multiplicity of factors contributing to risk, and the number of effective techniques in use, randomised trials seem unlikely to be undertaken. Comparison of outcomes in propensity matched pairs, as used by the Cleveland Clinic group, with comprehensive outcome measures, offers the best hope of advance. In the meantime, there seems little to choose between techniques, provided they are applied adequately, and are in the hands of their proponents.

REFERENCES

1 **Antunes PE**, Ferrão de Oliveira JM, Antunes MJ. Coronary surgery with non-cardioplegic methods in patients with advanced left ventricular dysfunction: immediate and long term results. *Heart* 2003;**89**:427–31.
2 **Shennib H**, Endo M, Benhamed O, *et al*. Surgical revascularization in patients with poor left ventricular function: on- or off-pump? *Ann Thorac Surg* 2002;**74**:S1344–7.
3 **Eagle KA**, Guyton RA, Davidoff R, *et al*. ACC/AHA guidelines for coronary artery bypass graft surgery: a report of the American College of Cardiology/American Heart Association task force on practice guidelines. *J Am Coll Cardiol* 1999;**34**:1262–346.
4 **Keogh BE**, Kinsman R. *National adult cardiac surgical database report 1999-2000*. Reading: Dendrite Clinical Systems Ltd, 2001.
5 **Trachiotis GD**, Weintraub WS, Johnston TS, *et al*. Coronary artery bypass grafting in patients with advanced left ventricular dysfunction. *Ann Thorac Surg* 1998;**66**:1632–9.
6 **Mickelborough LL**, Carson S, Tamariz M, *et al*. Results of revascularization in patients with severe left ventricular dysfunction. *J Thorac Cardiovasc Surg* 2000;**119**:550–7.
7 **Buckberg G**. Update on current techniques of myocardial protection. *Ann Thorac Surg* 1995;**60**:805–14.
8 **Cimochowski GE**, Harostock MD, Foldes PJ. Minimal operative mortality in patients undergoing coronary artery bypass with significant left ventricular dysfunction by maximization of metabolic and mechanical support. *J Thorac Cardiovasc Surg* 1997;**113**:655–66.
9 **Bonchek LI**, Burlingame MW, Vazales BE, *et al*. Applicability of noncardioplegic coronary bypass to high-risk patients. *J Thorac Cardiovasc Surg* 1992;**103**:230–7.
10 **Mack MJ**, Duhaylongsod FG. Through the open door! Where has the ride taken us? [editorial]. *J Thorac Cardiovasc Surg* 2002;**124**:655–9.
11 **Sabik JF**, Gillinov AM, Blackstone EH, *et al*. Does off-pump coronary surgery reduce morbidity and mortality? *J Thorac Cardiovasc Surg* 2002;**124**:698–707.