Beating heart coronary artery bypass surgery: less invasive coronary artery surgery

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Mr Vincent Young

Coronary Artery Bypass Grafting (CABG) is one of the most frequently performed operations worldwide. The reasons for this are twofold: firstly, the epidemic of ischaemic heart disease that has occurred in the twentieth century and secondly, the technical success of the operation. It has proved itself as one of the operations leading to the most dramatic improvement in quality of life in addition to prolonging life for most patients having surgery. Since the 1980s, mortality for the operation has fallen from 8% to 1-2% for routine CABG today.

One would imagine therefore that today's cardiac surgeons might almost be complacent: having reduced the mortality for such a major operation to a very acceptable one while giving very dramatic improvements in both of quality of life and survival. However, in common with many surgical sub-specialities, some cardiac surgeons have been asking themselves whether it might not be possible to achieve similar results less invasively. In many surgical specialities this has been termed 'minimally invasive surgery'. For this article I have used the term 'less invasive coronary artery surgery', as any operation on the heart will always carry a small but significant mortality and risk of serious complications. Over the last few years in particular, it has become evident that a number of less invasive approaches to surgically bypassing the coronary arteries are possible. One of these involves performing the operation without recourse to the cardiopulmonary bypass machine. These operations are often referred to as 'beating heart surgery' as, unlike conventional CABG, the heart continues to beat and support the circulation during the operation.

Cardiopulmonary bypass machine

The origins of cardiac surgery are intimately associated with the cardiopulmonary bypass machine. This machine has become so intimately associated with cardiac surgery that one could almost say that it has defined what cardiac surgery is, in that almost all cardiac surgery procedures are performed on a cardiac-pulmonary bypass machine (Figure 1). Much of the improvement in the results of cardiac surgery has been due to refinements in the cardiopulmonary bypass machine so that it is less damaging to the patient. However, exposure of the patient's blood to the artificial surfaces of the bypass machine including the plastic tubing and oxygenator leads to a wide range of undesired consequences (Table 1). There is widespread activation of inflammatory cytokines, neutrophils, platelets and to a lesser extent the coagulation cascade, all of which have been shown to be deleterious to the patients outcome. A percentage of patients will experience a systemic inflammatory response to surgery (SIRS) associated with low blood pressure in the context of a normally functioning heart. Some will develop 'pump lung' a form of the adult respiratory distress syndrome (ARDS). In addition, there is a definite incidence of renal failure associated with cardiopulmonary bypass. Perhaps the most dreaded complication of all is the development of stroke in the peri-operative period. Although in younger patients this is 2-3%, for patients over 75 it rises to 8%. Bypass has also been associated with more subtle neuropsychological impairment.

One must remember that the development of coronary artery surgery took place after the development of both valvular and paediatric heart surgery and at this stage cardiac surgeons were already accustomed to operating under the almost ideal operating conditions of a stable, motionless and bloodless heart. However this can only be achieved by using three measures:

1. Aortic cross-clamping: placing a clamp across the ascending aorta to isolate the heart from the rest of the circulation.
2. Myocardial protection: stopping the heart beating using cardioplegia.
3. Cardiopulmonary bypass: supporting the patient's circulation with the cardiopulmonary bypass machine while the heart is being operated on.

The adverse effects of cardiopulmonary bypass have been mentioned above. In addition, the act of placing a clamp on the aorta can dislodge atheromatous emboli which go to the head and neck vessels and cause stroke. Thirdly, no form of myocardial protection is perfect and there is always by definition some compromise of myocardial function in the immediate post-operative period related to the period of ischemia. Like many developments in medicine, progress involved stepping back in time to ask a question which could have been asked 30 years ago: why do we need to stop the heart in order to operate on vessels which are outside the heart?

Figure 1. Cardiopulmonary bypass machine.

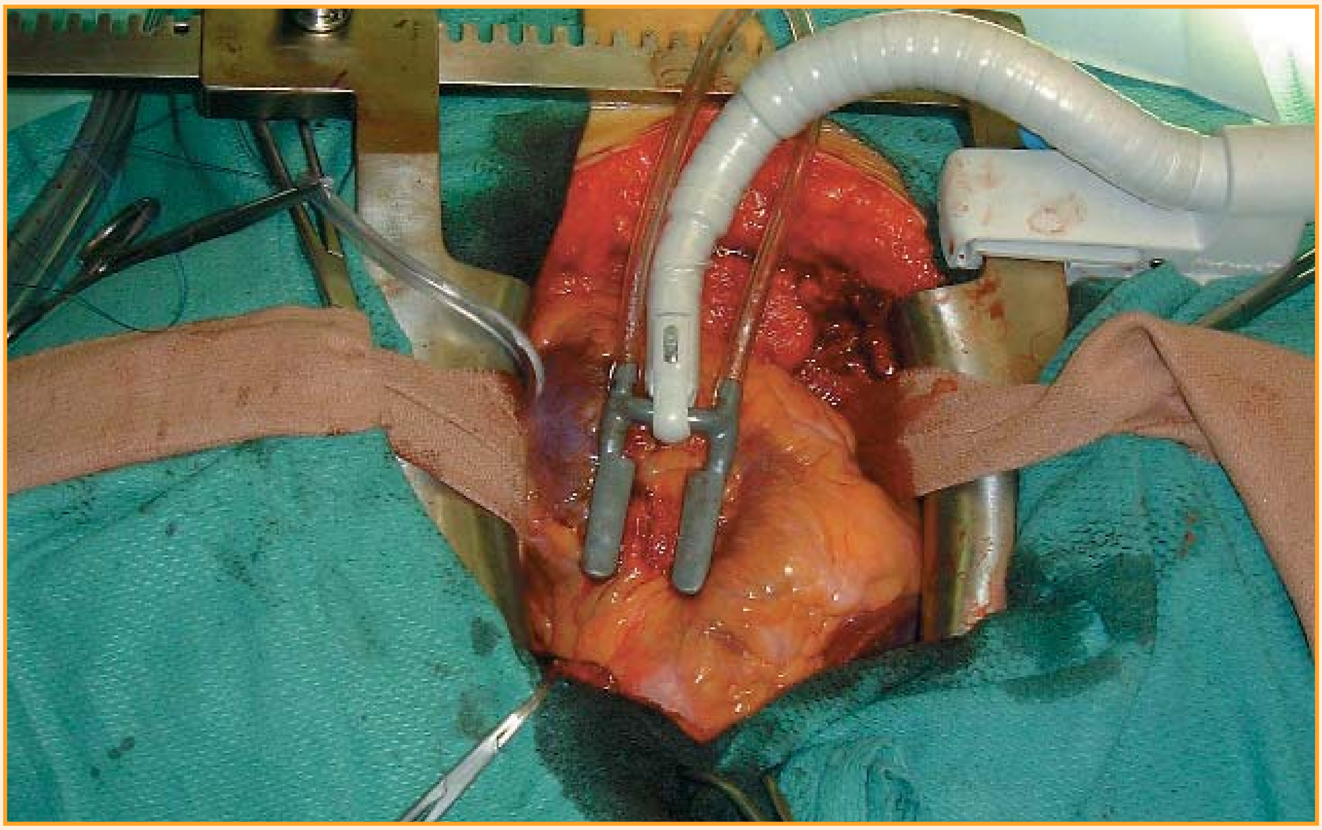


Figure 3. Octopus applied to heart.

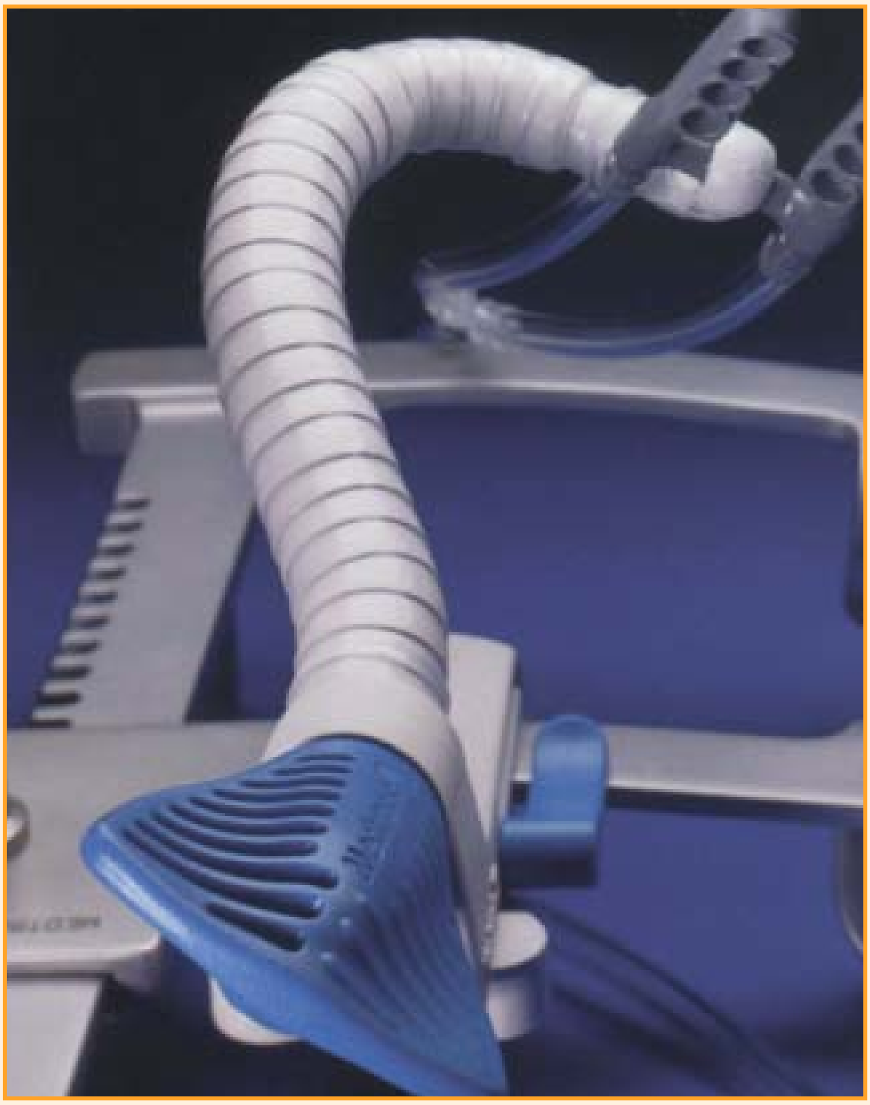


Figure 2. Octopus stabiliser.

Off-pump CABG

Whether 'beating heart surgery' can be performed successfully depends on two further questions.

1. Is it technically possible to perform a good anastomosis on a moving target?
2. Is it possible for the heart to support a patient's circulation while it is being moved into the abnormal positions required to perform the anastomoses?

A huge bonus in this area has been the advent of commercially available stabilising devices such as the Octopus (Figure 2). This device uses a series of suction pads which are applied to the external surface of the heart. Suction keeps the pads adherent to the heart and the flexible arm can be moved into a variety of positions before it is locked. This provides a stable operating field, immobilising the coronary artery while allowing the heart itself to continue to beat (Figure 3). This is more easily performed on vessels on the front of the heart such as the LAD and right coronary artery. Grafting branches of the circumflex requires considerable displacement of the heart out of the pericardial cavity. Such acute displacement is usually associated with profound haemodynamic compromise. However, it has been learned that by the adequate filling of the patient and a variety of other manoeuvres, it is possible to maintain adequate cardiac output. Intra-operative monitoring using trans-oesophageal echo or continuous cardiac output measurements is useful. The second technical measure which has aided the performance of the anastomosis is the use of small temporary intra-coronary shunts which maintain blood flow through the vessel being operated on, while the anastomosis is being performed (Figure 4). These two measures have meant that many surgeons are now adopting this technique for at least some of their caseload. Patients who are particularly suitable are those with more technically straightforward grafts, especially on the anterior surface of the heart or patients for whom the risks of cardiac pulmonary bypass are increased, such as those with compromised renal function or a high risk of stroke. Already there is evidence that this technique decreases the stroke rate in octogenarians. It is also subjectively associated with a more rapid patient recovery, as patients do not experience the flu-like symptoms that frequently occur following cardiopulmonary bypass.

Figure 4. Temporary intra-coronary shunt.

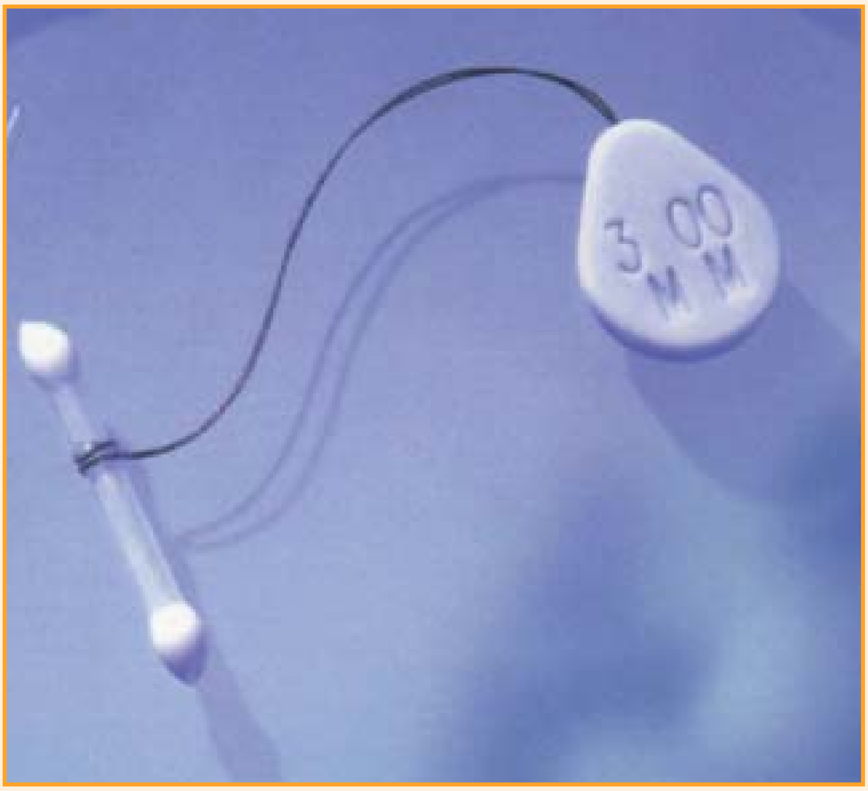
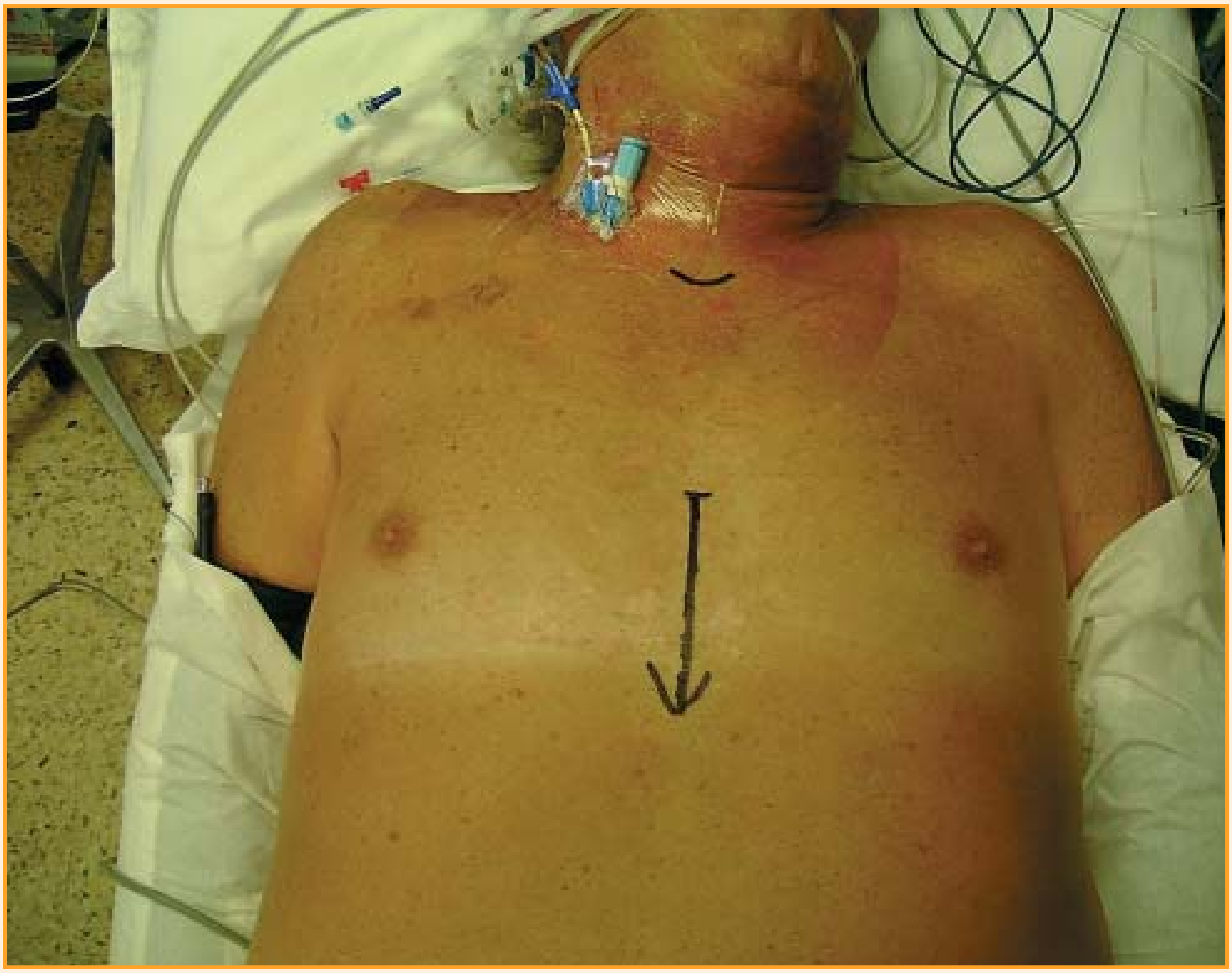


Figure 5. Extent of limited lower sternotomy incision.



Smaller incisions

Even this technique involves a standard median sternotomy, and from the external appearances the patient may not be aware of the difference in the operation. An even more recent development which we have been performing at St James's Hospital is the use of a limited lower sternotomy (see Figure 5) to gain access to the LAD. The incision is approximately 10cm long and leaves most of the sternum intact. Through this incision the left internal mammary artery can be harvested and anastomosed to the LAD by using the stabilisation device without using cardiopulmonary bypass. This technique offers the dual advantages of avoiding the adverse effects of cardiopulmonary bypass, but also a very small incision in the lower chest. These patients are usually extubated in the operating theatre and spend a few hours in intensive care before being transferred to the ward. Routine discharge for these patients is on the second post-operative day and many of them can return to work, including manual occupations, within a few weeks.

Conclusions

In summary, 'beating heart surgery' has already established a niche for itself in coronary artery surgery. What percentage of operations will ultimately be performed without cardiopulmonary bypass machines remains to be seen and this is certainly likely to increase with time. Benefits in stroke rate, early discharge and renal failure have already been shown. Investigations showing more subtle neuropsychological benefits to this procedure relative to conventional coronary artery surgery are ongoing and perhaps these will turn out to be the most exciting of all. It is obviously important in the development a new technique that the excellent results of coronary artery bypass surgery are not compromised, but again, results so far indicate that this operation can be performed with equal or lower mortality.

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Table 1.

Organ dysfunction following cardiopulmonary bypass.

Organ	Complications
Brain	Stroke and neuropsychological impairment
Kidney	Renal impairment
Gastrointestinal	Gut ischaemia and infarction
Lung	ARDS and collapse
Systemic	Systemic inflammatory response (SIRS)