OPCAB surgery: a voyage of discovery back to the future

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Introduction
The resurgence of off-pump coronary artery bypass (OPCAB) surgery is rapidly changing surgical practice. After an initial phase of ‘healthy skepticism’, the impetus of some developed countries toward OPCAB surgery is remarkable. Hardly any OPCAB procedure was carried out before 1995 in the USA, however, by 1999 more than 11 000 (10%) coronary operations were performed on the beating heart.1

It is estimated that, worldwide, this percentage is currently up to 20–30%, with expectations to reach 50% by 2005.2–3 Many sceptics have become optimists following the development of enabling instruments and the publication of supportive evidence as part of observational, case-matched, and prospective randomised studies.

Historical aspects
The concept of direct mammary–coronary anastomoses was advocated separately by Demikhov and Murray in animal models in the early 1950s.4–5 The first saphenous vein graft to bypass the right coronary artery was performed by Sabiston on the beating heart in 1962.6 Kolesov performed the first mammary–coronary anastomosis, on the beating heart in a human, in 1964.7 After the advent of the heart–lung machine, few surgeons continued to use the OPCAB technique, and when they did it was for economic reasons.8–9 Among those were Benetti8 and Buffolo9 from South America, who published in the early 1990s the first two large series on OPCAB surgery. These results, as well as the interest in minimally invasive coronary surgery through minithoracotomy approaches, prompted the development of enabling systems and devices that ultimately made the OPCAB a safe and routine procedure.

The rationale
Despite advances in perfusion, anaesthetic and surgical techniques, cardiopulmonary bypass (CPB) is still associated with significant morbidity due to its un-physiological nature. The morbidity rate has indeed remained high, particularly in the ever-increasing high-risk surgical population presenting with co-morbidities. Contact of blood components with the artificial surfaces of the bypass circuit, aortic cross-clamping and reperfusion injury are considered the main causative factors of inflammatory response following cardiac surgery. Furthermore, nonpulsatile flow, hypothermia, duration of CPB, hypoperfusion, and microemboli of gaseous or particulate nature all contribute to end organ injury.10–15 OPCAB surgery, by means of avoiding CPB and cardioplegic arrest, is expected to produce significant benefits. Ideally OPCAB surgery should at least equal conventional surgery in terms of mortality while improving in-hospital morbidity and maintaining the excellence of long-term clinical outcome. The relatively simple technology required and reduced hospitalization costs may make coronary surgery available to undeveloped countries.

Indications
In the absence of recognized guidelines, patient selection criteria are still unclear and the first approach is often the surgeon’s ‘common sense’. Theoretically, there are no limitations to the application of OPCAB surgery, but in practice it varies from 0 to 100% depending on the phase of the
learning curve of each surgeon. Common sense suggests that a surgeon starting an OPCAB programme should consider avoiding dilated or poor left ventricles, very small, intramyocardial, or diffusely diseased vessels, and haemodynamically unstable patients with recent myocardial infarction. Preventing conduction and haemodynamic deterioration when positioning the beating heart to graft on the lateral and posterior walls is also of paramount importance. This can be achieved with a combination of surgical manoeuvres, including the Trendelenburg, fluid administration, increments of vasoconstrictor agents like metaraminol, and inotropes if necessary. Intracoronary shunts have been introduced to prevent snaring-related injury of the coronary vessels and to allow myocardial perfusion during the construction of the anastomoses. Finally, excessive motion of the coronary target, a main concern as a potential cause of suboptimal anastomoses, has been overcome with the introduction of either pressure or suction retractor-stabilizers.

The evidence

The initial ‘healthy skepticism’ against OPCAB surgery, was based on the potential for intra-operative myocardial ischaemia, suboptimal anastomoses, and a protracted learning curve. In contrast, the initial ‘gut feeling’ enthusiasm of others was based on the potential of reducing morbidity while allowing undeveloped countries to access a programme of coronary surgery at reduced cost. This debate has provoked an increasingly rigorous process of scientific validation in several centres. The result has been a large number of observational, case-matched, and prospective randomized trials.

BHACAS 1 and 2 trials

The Beating Heart Against Cardioplegic Arrest Studies (BHACAS 1 and 2) were two single-centre randomized trials carried out at the Bristol Heart Institute on a total population of 401 (200 off-pump) elective patients. The main aim was to compare early and mid-term morbidity and use of healthcare resources. In-hospital mortality did not differ between groups (1% and 0% on- vs off-pump). However, benefits associated with OPCAB surgery included significant reduction of chest infection, inotropic requirement, arrhythmias, total chest tube drainage and consequent transfusion requirement, intubation time, intensive care, and hospital stay. In subgroups of the same population we also showed that off-pump surgery reduces inflammatory activation, myocardial injury, renal damage, and injury to the blood-brain barrier.

An economic analysis showed off-pump surgery to be cost effective, with a saving of about 25% per patient when compared to conventional revascularization.

One of the major criticisms against OPCAB surgery has been the performance of suboptimal anastomoses with the potential for poor long-term results. This possibly has been the main reason preventing a more generalised use of the technique. The results of the pooled analysis of our two trials showed a mean follow-up of 25.0 months (SD 9.1) for BHACAS 1, and 13.7 months (5.5) for BHACAS 2. Pooled survival estimates at 24 months were 96% (CI 91–98) and 97% (92–99) for the on-pump and off-pump groups, respectively. Myocardial infarction and recurrence of angina were 4% vs 2%, and 14% vs 12% in the on-pump and off-pump groups respectively. Six (3%) patients in the on-pump and seven (4%) in the off-pump group required repeat catheterization. Four out of these 13 patients showed no evidence of stenotic grafts or progression of coronary disease. There was no evidence of a stenotic graft in the remaining nine patients, but four (2%) patients in each group required a PTCA procedure on new stenotic lesions, and one (0.5%) in the off-pump group needed repeat surgical revascularisation. Pooled estimates for survival free from any cardiac-related event at 24 months were 78% and 84% for the on- and off-pump groups, respectively. No significant differences were recorded in the frequencies of any non cardiac-related events between groups. Medications taken at follow-up also did not significantly differ between groups. These results strongly suggest that the expressed concern of suboptimal anastomoses with OPCAB surgery is not justified.

Other evidence to date

The outcome of a multicentre randomized trial in a cohort of 281 patients (142 off-pump) was reported by van Dijk and co-workers, with no difference in terms of in-hospital mortality and morbidity. The off-pump patients, however, had a shorter ventilation time, were discharged 1 day earlier and had a reduction of 41% release of CK-MB when compared to the on-pump patients. A review of the outcome of 118 140 CABG-only procedures of the STS National Adult Cardiac Surgery Database has been recently published. Of these, 11 717 (9.9%) were off-pump procedures. A risk-adjusted analysis showed significant benefits associated with OPCAB surgery, including reduced operative mortality (from 2.9% to 2.3%), and major complications such
as deep sternal infection, bleeding, renal failure, and prolonged ventilation (from 14.1% to 10.6%). Similar results were reported by Plomondon et al.18 in a large prospective cohort study from the VA Continuous Improvement in Cardiac Surgery Program. Calafiore et al.19 in 1843 consecutive patients (919 off-pump, 49.9%) also reported a significantly lower in-hospital mortality, perioperative MI, cardiovascular accident (CVA), and early major complications in the off-pump compared to the on-pump group. In a similar retrospective comparison by Hernandez et al.25 of 6126 conventional CABG vs 1741 OPCAB procedures, in-hospital mortality, major complications such as mediastinitis, stroke, and reopening for bleeding were similar between groups, although OPCAB surgery resulted in a statistically significant reduction in need for IABP, and incidence of post-operative atrial fibrillation. Recently, Magee et al.26 in 8449 CABG procedures (1983 OPCAB) in a multivariate logistic regression analysis found CPB to be an independent predictor of mortality.

High-risk patients might benefit the most from OPCAB surgery. We recently investigated the incidence of early mortality and morbidity in 1570 consecutive high-risk CABG-only patients (332 (21.1%) undergoing OPCAB surgery) selected by: age >75, ejection fraction <30%, recent MI (<1 month), current congestive cardiac failure, previous CVA, serum creatinine >130 µmol, respiratory impairment, peripheral vascular disease, redo surgery, and intraoperative endarterectomy.27 After adjustment for known prognostic factors, the majority of the variables investigated showed benefit associated with OPCAB surgery, and this was highly statistically significant for transfusion requirement, ICU and hospital stay. In another study,28 253 patients with preoperative serum creatinine >150 mol.l⁻¹ were identified, and these included 51 patients undergoing OPCAB surgery. A multiple logistic regression analysis showed CPB inclusive of cardioplegic arrest to be an independent predictor of acute renal failure (ARF). Magee et al.,29 in a retrospective study on the influence of diabetes mellitus on mortality and morbidity, found that diabetic patients undergoing OPCAB surgery had a significantly lower incidence of post-operative ARF when compared with patients undergoing conventional surgery. A recent study performed at our institution on obese patients, after adjustment for confounding variables, showed that off-pump surgery was associated with a significant benefit for in-hospital mortality, intraoperative arrhythmias and inotropic use, postoperative blood loss, transfusion requirement, chest infections, low cardiac output, use of IABP, and neurological complications including stroke, intubation time, ICU and hospital length of stay.30 Evidence supporting the use of OPCAB surgery in elderly patients has also been provided, with a decreasing rate of major post-operative complications, including low-output syndrome, atrial fibrillation, blood usage, prolonged ICU and hospital stay.31–32

Finally, several prospective studies have also focused on the impact of OPCAB surgery on subsystem organ function showing, when compared to conventional surgery, a significant attenuation of inflammatory activation,33 less myocardial injury as suggested by a lower release of troponin I or CK-MB,17,33 and reduced cerebral injury as assessed by serum S100 protein release.23,34 The results on cognitive dysfunction, however, are conflicting, either lower23,35 or similar34,36 during OPCAB, when compared to conventional surgery.

Conclusion
First pioneered in the early days of coronary revascularisation, OPCAB surgery was soon abandoned due to the advent of the heart–lung machine. However, the voyage of discovery of OPCAB surgery continued thanks to the enthusiasm of a few surgeons and their desire to simplify coronary artery surgery techniques. In the 1990s they exposed themselves to the ‘healthy skepticism’ of the scientific community given the excellent results of conventional coronary surgery, the best validated surgical procedure ever. From the initial view that OPCAB surgery was ‘a triumph of technical skill over common sense’ as ‘a surgeon's ego trip’ the voyage continued, mostly along the road of developing enabling instruments and techniques to improve exposure and stabilisation during construction of the coronary anastomosis. The result is that OPCAB surgery is now a proven, safe, cost effective and reproducible surgical technique, in effect ‘a triumph of simplicity’.

References


