SPECIAL ARTICLE

Off-Pump Coronary Artery Bypass Surgery

Anaesthetic Implications and The Trinidad Experience

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ABSTRACT

Objectives: *To review the evolution of off-pump coronary artery bypass surgery with particular reference to the anaesthetic and perioperative implications.*

Findings: *After review of the literature regarding coronary artery bypass grafting, the adverse effects of cardiopulmonary bypass on the various systems are discussed. The development and the present status of off-pump coronary artery bypass surgery and its anaesthetic implications are reviewed. These are discussed under the categories of preoperative, intra-operative and postoperative concerns. In Trinidad and Tobago, various cardiac surgical teams from different parts of the world conduct cardiac surgery. The cardiac anaesthesia team therefore has the unique opportunity of working with several teams who employ different techniques.*

Conclusions: *Off-pump coronary artery bypass grafting surgery has distinct anaesthetic implications. In Trinidad and Tobago, the majority (85%) of the coronary revascularization surgeries are being done by this technique. Because of the lower cost and improved outcomes, this technique could be recommended to other developing countries of the region.*

Cirugía de Bypass Coronario sin Circulación Extracorpórea

Implicaciones Anestésicas y la Experiencia de Trinidad

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RESUMEN

Objetivos: *Examinar la evolución de la cirugía de bypass coronario (revascularización coronaria) sin circulación extracorpórea, con referencia particular a las implicaciones anestésicas y perioperatorias.*

Hallazgos: *Tras examinar la literatura en relación con el bypass coronario con injerto, se discuten los efectos adversos del bypass cardiopulmonar en los distintos sistemas. Se analiza el desarrollo y el estatus presente de la cirugía de bypass coronario sin circulación extracorpórea ("sin bomba") y sus implicaciones anestésicas. El análisis se realiza bajo las categorías de problemas pre-operatorios, intra-operatorios y post-operatorios. En Trinidad y Tobago, varios equipos de cirugía cardiaca de diferentes partes del mundo llevan a cabo cirugía cardiaca. Por lo tanto, el equipo que tiene a su cargo la anestesia durante las intervenciones quirúrgicas del corazón tiene la oportunidad excepcional de trabajar con varios equipos que emplean diferentes técnicas.*

Conclusiones: *La cirugía de injerto de bypass coronario sin circulación extracorpórea tiene claras implicaciones anestésicas. En Trinidad y Tobago, la mayoría (85%) de las cirugías de revascularización coronaria, se realizan mediante esta técnica. Debido a su bajo costo y al mejoramiento en sus resultados, esta técnica podría recomendarse a los países en desarrollo de la región.*

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INTRODUCTION

Many practices in medicine have gone through a full cycle. Some techniques practised during the early days of discovery were pushed into the background by future developments, only to be reintroduced at a later date with the further evolution of the techniques.

Coronary artery surgery is not an exception to this phenomenon. Although there was a report on "beating heart" surgery as early as 1910 (1), it went into oblivion when cardiopulmonary bypass technique came into vogue, which became the most preferred technique for coronary artery bypass grafting (CABG) (2). Later, beating heart surgical technique was revisited and there was a report of internal mammary artery anastomosis with coronary artery in 1967 (3). Presently, CABG without bypass has been found to have better outcome than the conventional bypass technique to the extent that some authors have queried whether off-pump surgery should be the routine technique in all patients requiring CABG (4).

Off-pump coronary artery bypass grafting (OPCAB) has unique anaesthetic considerations. This article is a review of the anaesthetic implications and a comparison of the practice in Trinidad and Tobago where visiting surgical teams from various parts of the world undertake this type of surgery.

The setting in Trinidad and Tobago

Cardiac surgery in Trinidad and Tobago started in 1993 at the Eric Williams Medical Sciences Complex, a tertiary care teaching hospital affiliated to the University of the West Indies. The Caribbean Heart Care (presently CHC – Medcorp Limited) Trinidad, is responsible for conducting different types of elective and urgent cardiac surgeries in all age groups in Trinidad and Tobago. The surgeries are done at two centres namely the Eric Williams Medical Sciences Complex, and the St Clair Medical Centre, a corporate hospital offering tertiary care services. Surgical teams visit Trinidad and Tobago from Venezuela, the United Kingdom, France, Italy and Brazil. The services of the anaesthetists, perfusionist and the nursing staff are provided locally. All patients are admitted postoperatively to intensive care units (ICU) under the care of an intensivist, and later transferred to the high-dependency units.

Off-pump coronary artery surgery has been done in Trinidad and Tobago since 1997 and more than 600 off-pump surgeries have been completed. The proportion of surgeries done off-pump increased from 15% in 2001 to 50% in 2002 and is further increasing with the present estimates being around 80–85%. The overall mortality rate for OPCAB surgeries during the period of 1997 to 2002 was 2.6% compared to 4.6% for CABG on pump.

DISCUSSION

Evolution of off-pump coronary artery bypass surgery (OPCAB)

Although the number of patients suffering from coronary artery disease is on the rise, the number of patients referred for surgery is declining in the United States of America. This is predominantly because of the angioplasty techniques which have evolved recently as the preferred technique. The latest statistics show that 41.9% of the coronary revascularization procedures are done by angioplasty and stenting techniques in comparison to surgery, which is only 17.9% (5).

The major physiological trespass associated with the institution of cardio-pulmonary bypass (CPB) during conventional CABG may be one of the primary reasons for the static or downward trend of conventional CABG surgery. Most of the vital organs such as lungs, kidneys, splanchnic bed and the brain are affected by CPB. The effects of aortic cross-clamping as well as micro-emboli of atheromatous plaques are responsible for both short-term and long-term neurological dysfunction associated with CPB (6). Cerebral ischaemia may also be precipitated by low cerebral perfusion and venous obstruction which may further contribute to postoperative neurocognitive dysfunction (7).

Extracorporeal circulation may serve as a trigger to systemic inflammatory response which activates the cellular and humoral mediators of the blood. This sequentially leads to inflammation and destruction of the cellular membranes of the body organs (8). Additionally, generalized arterial hypoperfusion may be responsible for the development of renal dysfunction, varying degrees of acute lung injury causing increased shunting, and also hepatic and other splanchnic dysfunction.

Many patients undergoing CABG suffer from co-morbid illnesses such as diabetes mellitus, peripheral vascular disease and hypertension. These patients are more susceptible to microvascular disease and the effect of CPB.

The major causes of coagulopathy associated with CPB are release of fibrinolysins, platelet dysfunction caused by the CPB circuit as well as heparin and consumption of coagulation factors (9). In many patients, organ system dysfunctions may go unnoticed because of their sub-clinical manifestations. There is now increasing evidence for increased end-organ injury following CPB, compromising renal, myocardial and respiratory functions (10–12). Hence it is not surprising that the semi-invasive angioplasty and stenting techniques in catheterization laboratories challenge the cardiac surgeons. This has also served as an impetus for the revisiting of off-pump techniques. OPCAB has reduced the incidence of renal, neurological, respiratory and haematological dysfunction (13–16).

Anaesthetic implications of OPCAB

In contradistinction to CABG technique on CPB, the OPCAB requires more involvement from the anaesthetist's point of view because maintenance of homeostasis is completely in the hands of the anaesthetist, whereas in the former technique, it is shared with the perfusionist. The anaesthetic considerations will be discussed under three sections – preoperative, intra-operative and postoperative implications.

Preoperative implications

Preoperatively, a thorough clinical history, examination and assessment of the patient are essential, with special attention

to the class of angina and effort tolerance, which may indirectly point to the allowable level of fluctuations in the haemodynamics intraoperatively. Adequate communication between surgeon and anaesthetist is very important so that a complete anaesthetic plan may be charted. Premedication may help to avoid tachycardia, which may adversely affect the coronary artery demand-supply balance. In Trinidad and Tobago, the anaesthetists evaluate all patients on the previous day by the Parsonnet scoring system (17). Benzodiazepines such as lorazepam are prescribed orally as premedicant drug on the night before the surgery. Some patients receive oral midazolam on the morning of the surgery. In accordance with the surgical techniques employed by the visiting team, the anaesthetic plan is formulated preoperatively.

Intra-operative implications

Monitoring considerations

Routine monitors such as pulse oximetry, capnography, invasive arterial blood pressure, central venous pressure, core and peripheral temperatures and urinary output should be invariably included as in any other cardiac surgery. A 5-lead electrocardiograph (ECG) to detect dysrhythmia and ischaemia is essential. Because of the retraction and displacement of the heart, the ST-T changes may not be very prominent and even the regular waveform may have artifactual distortions (18). The role of "maximal" monitoring with trans-oesophageal echocardiography (TOE) and pulmonary artery catheter (PAC) in OPCAB is controversial.

The value of TOE in detecting ischaemia very early has been well demonstrated in open-heart surgery (19), although its role in beating heart surgery is unclear. This is perhaps because of the retraction and constantly varying positions of the heart, which make interpretations much more difficult, and recently high frequency epicardial echocardiography has been suggested as a useful monitor for OPCAB (20). In experienced hands, TOE may play a vital role in not only detecting intraoperative ischaemia but also to monitor haemodynamic disturbances due to other causes such as mitral annulus distortion (21). However, TOE is not an effective monitor for directly assessing the adequacy of coronary anastomosis.

Routine use of PAC for measuring pulmonary capillary wedge pressure as well as cardiac output measurement remains controversial in beating heart surgery (22, 23). However, if the PAC has an incorporated oximetry facility, the continuous measurement of mixed venous oxygen saturation is considered to be an invaluable monitor. In fact, mixed venous oximetry has been suggested as one of the essential monitors (24). This provides vital information regarding not only the delivery of oxygen (DO_2) (indirectly reflecting the arterial oxygen tension, cardiac output and the haemoglobin concentration), but also the tissue oxygen extraction and consumption. Retraction and displacement of the heart during OPCAB surgery most often cause reduction in cardiac output which may be effectively monitored by the mixed venous oxygen saturation (25). Recently, the bispectral index monitor (BIS) has been suggested as one of the valuable monitors to detect cerebral hypoperfusion during OPCAB (26).

Thus "maximum" monitoring with TOE and PAC may not be required routinely for all OPCAB surgeries and is more useful in patients who have had preoperative left ventricular dysfunction. In Trinidad and Tobago, TOE and PAC monitors are not used, although PAC is used in rare haemodynamically unstable patients who require prolonged ICU stay.

Haemodynamic considerations

As mentioned earlier, OPCAB surgery is invariably associated with hypotension due to reduction in cardiac output caused by retraction and displacement of the heart, especially during anastomosis of the circumflex artery (27). Anastomosis for left anterior descending and posterior descending arteries may cause reduction in cardiac output and hypotension (28).

The suggested measures to avoid severe hypotension include volume preloading, head-down tilt and α-adrenergic agonist agents such as phenylephrine (29). In Trinidad and Tobago, the α-adrenergic agonist commonly used is metaraminol. If hypotension is refractory, a potent vasopressor agent such as noradrenaline should be started immediately. Thus the anaesthetist should be proactive and constantly watch the surgical procedure and communicate with the surgeon so that appropriate measures may be taken immediately. Sometimes, simple measures such as release of retraction and repositioning the heart may be all that is necessary to correct the hypotension (30). At the behest of a surgical team, the authors attempted to use a prophylactic low-dose infusion of noradrenaline to avoid severe haemodynamic instability; however, this proved to be more disadvantageous in most patients because of the sudden drop in blood pressure after discontinuing the infusion in the early postoperative period.

In patients who are assessed to have some degree of left ventricular dysfunction preoperatively and might be unable to tolerate hypotensive episodes, prophylactic placement of the intra-aortic balloon pump after induction of anaesthesia may help in managing intraoperative hypotension effectively by counterpulsation (31). This is also practised in Trinidad and Tobago.

On the other hand, systolic blood pressure should be well controlled in hypertensive and normotensive patients, since high systolic blood pressure may predispose to aortic dissection during proximal graft anastomosis (32). In Trinidad and Tobago, intravenous nitroglycerine is used to reduce the blood pressure, but some surgeons prefer that the anaesthetist use volatile and intravenous anaesthetic agents for this purpose.

During the early days of beating heart surgery, anaesthetists induced bradycardia to facilitate surgeons

working on a slowly beating heart (33). However, advances in stabilization techniques and equipment have negated the need for this procedure. Additionally, many drugs used for slowing the heart rate also have a negative inotropic effect which could be further detrimental to the patient. Tachycardia should be meticulously avoided because it may cause adverse impact on coronary demand-supply. Some centres use adenosine intermittently to control the heart rate and even cause a transient asystole (34). Most patients in Trinidad and Tobago receive atenolol orally as premedication and intravenous esmolol is used intra-operatively to reduce inadvertent tachycardia.

Dysrhythmias, a major complication, may occur because of displacement of the heart and reperfusion (35). Maintenance of normokalaemia and magnesium supplementation may minimize this risk (36).

Anticoagulation and normothermia

Anticoagulation strategies vary with institutional choices, some opting for partial heparinization and some complete (37). An activated coagulation time of just above 250 seconds is most often adequate for OPCAB surgery which is usually reversed at the end with protamine.

Prevention of hypothermia by using warming blankets and warm intravenous fluids should be remembered, since most cardiac anaesthetists used to CABG on-pump may not be attentive to temperature maintenance.

Intra-operative cardiac protection against ischaemia

Ischaemic preconditioning is a technique by which, brief periods of coronary occlusion (5 minutes) and reperfusion may condition the heart to tolerate longer periods of ischaemia which may follow later (38). This technique has proven useful in animal models initially. Subsequently, it was tested in humans (39) but preconditioning may not totally prevent ischaemic injury to myocardial cells though it may delay its occurrence. There have been many studies recently suggesting that this technique may prevent dysrhythmia during CABG (35, 40, 41). However, the overall clinical evidence is not sufficient to recommend this technique as a routine during OPCAB surgery (42).

Drugs such as α-adrenergic blockers and calcium channel blockers may be used to protect against ischaemic events, although one should be careful because of their negative inotropy. Intravenous nitroglycerine infusion is recommended when there is not much haemodynamic instability, because of the associated reduction in preload. Nitroglycerine is the preferred drug for protection against ischaemia (43), and is the usual drug of choice for this purpose in Trinidad and Tobago.

Surgical techniques

Off-pump coronary artery bypass surgery may be done either by midline sternotomy or alternative techniques. One common alternative approach is left lateral thoracotomy – minimally invasive direct coronary artery bypass (MIDCAB) – which is very useful in high-risk patients with multiple vessel disease (44). Left lateral thoracotomy approach is employed commonly in Trinidad and Tobago with good results, even in morbidly obese patients.

Other approaches include right thoracotomy, left anterior small thoracotomy (LAST) to access the left anterior descending artery (LAD), parasternal and subxiphoid incisions, robot assisted endoscopic revascularization and laser revascularization through thoracotomy (45–47).

As mentioned earlier, advances in the stabilization equipment has revolutionized OPCAB surgery. The commonly used stabilizer is the Octopus stabilizer, and its second version is used in Trinidad and Tobago (Fig. 1). In addition, Angelini's stabilizer (Fig. 2) developed by the Bristol Heart

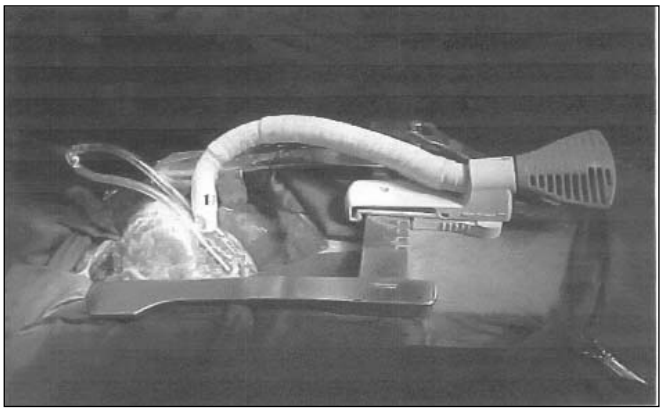

Fig.1: Octopus II Stabilizer
1. The part of the stabilizer which retracts and holds the heart
2. Suction equipment to clear the field of anastomosis

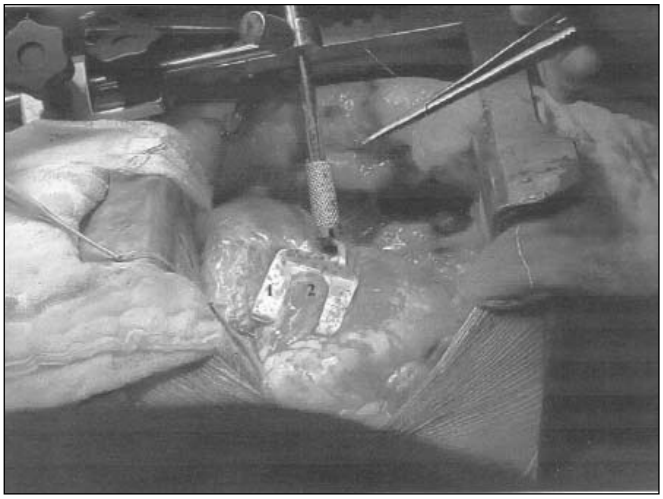

Fig. 2: Angelini Stabilizer
1. Metal stabilizer to hold the heart in position during anastomosis
2. The area of anastomosis

Institute of the United Kingdom, is also being used in Trinidad and Tobago. An apical suction device (Fig. 3) is also commonly used to stabilize the beating heart. These devices facilitate speedy surgery and minimize the mani-

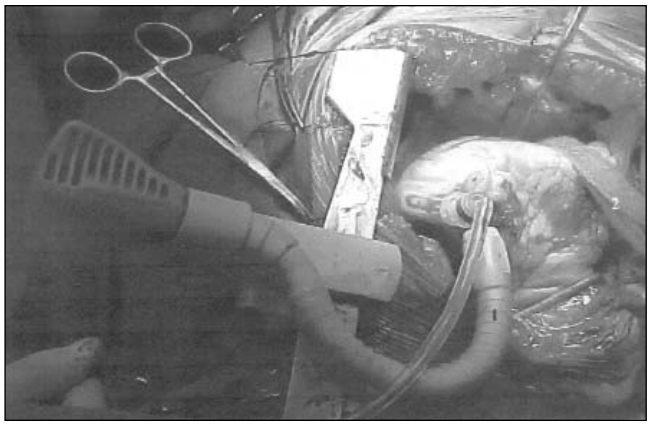

Fig. 3: Apical suction device
1. Constant suction of the apex vertically displaces and holds the heart
2. Retraction by gauze

pulations of heart and vessels, and thus indirectly reduce the requirement for inotropes, and the need for induced bradycardia (48–50).

Other innovative devices used in OPCAB surgery are the aortic connector system, to reduce aortic manipulations and to minimize the embolization of debris from aortic wall during side-clamping and the Med – RHS device, which supports the right heart by enhancing flow during posturing.

The grafting strategy employed typically during OPCAB is to first anastomose the left internal mammary artery (LIMA) to the left anterior descending artery (LAD). Proximal anastomoses are usually done prior to distal ones, which is the reverse of what is usually done for on-pump CABG. The diagonal artery, main trunk of the right coronary artery, posterior descending artery, distal circumflex, obtuse marginals, posterior lateral artery and ramus intermedius artery anastomosis are done in that order due to increasing difficulty in approaches (51). In Trinidad and Tobago, OPCAB started with single vessel disease patients and currently multi-vessel anastomoses are done, the highest number of grafts being five.

Postoperative implications

The most important benefit of OPCAB over conventional CABG is the early extubation and ambulation of the patient (52). This would mandate a better form of analgesia in the postoperative period. Short acting opioids such as remifentanil, which may be used during the surgery, may not be useful in the postoperative period. Thoracic epidural anaesthesia has been suggested as an alternative method of analgesia, due to the additional advantage of the attenuation of stress response to surgery (53). The attendant complications such as bleeding and epidural haematoma may be avoided by placement of the catheter preoperatively before the institution of anticoagulation, and its removal when anticoagulation is stopped. Some authors in fact have reported OPCAB exclusively under thoracic epidural anaesthesia and plexus blocks for harvesting arterial and venous grafts (54), and continue to practice this technique in awake patients despite there being an opinion that there are more disadvantages than advantages in this technique (55).

Continuous interpleural analgesia with a catheter placed in the interpleural space is an attractive alternate technique. In Trinidad and Tobago, this technique is used in patients who undergo lateral thoracotomy and ropivacaine is the preferred drug. Patient control analgesia is another technique employed with good results (56) in Trinidad and Tobago.

Despite recommendation for extubation on the operating table, this is not practised at this centre and patients are electively mechanically ventilated in the ICU, although for a shorter time (2–3 hours on an average), and then extubated in the ICU.

Overall benefits of OPCAB

The outcome studies have varying results, and the mortality associated with OPCAB compared to CABG on CPB is comparable or less (57, 58). The morbidity is well reduced in patients undergoing OPCAB. Shorter ICU and hospital stays, less blood loss and the need for transfusion, avoidance of the adverse effects of CPB stated previously and overall better outcome with respect to risk-adjusted mortality are well documented with OPCAB (59–62). A recent paper has reported same day discharge following multi-vessel OPCAB (63). All these contribute to not only patient satisfaction but also cost benefits when compared to conventional CABG under CPB (64).

The limitation of OPCAB is the technical difficulty and it has been postulated that this may potentially contribute to decreased patency of the graft. However, many studies have reported excellent patency rates almost equal to conventional CABG (65). The need for CPB equipment may be essential as a stand-by, although the conversion rates have plummeted in recent years. However, emergency conversion from OPCAB to CPB has been associated with increased morbidity and mortality (66). There is a change in the outcome of patients if they are subjected to reoperation following OPCAB surgery (67). There have been other reports of non-arteritic anterior ischaemic optic neuropathy (NAION) and increased morbidity in diabetic patients following OPCAB, although these are sporadic (68, 69).

In Barbados, 27% of CABG surgeries are done off-pump and there was a significant reduction in the mortality and ICU length of stay in elderly patients who had OPCAB (70). Elderly patients, patients with low ejection fraction preoperatively, patients with significant co-morbid illnesses such as stroke, chronic obstructive pulmonary disease (COPD) and bleeding disorders may be earmarked for OPCAB. Studies have affirmed the further reduction in the incidence of stroke in susceptible patients (71, 72).

Off-pump coronary artery bypass reduces the overall morbidity and mortality of cardiac surgical patients along with improvement in their quality of life. A recent meta-

analysis has also confirmed the benefits of OPCAB when compared to conventional CABG (73). It is not surprising that OPCAB has been speculated to be the preferred coronary artery surgery for the next decade (74).

In summary, anaesthetists in Trinidad and Tobago are afforded a wide experience because of the unique situation of working with various visiting teams of surgeons. The many benefits of OPCAB surgery over CABG with cardiopulmonary bypass have been proven and have continued to be realized in high risk patients as the technique becomes more widespread. So far, the outcome of OPCAB has been encouraging in Trinidad and Tobago as evidenced by the increasing proportion of patients undergoing this technique uneventfully and may be recommended to other developing countries in the region.

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