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Off pump coronary artery bypass graft

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Introduction

Coronary artery bypass graft (CABG) using a graft anastomosed between the aorta and the coronary artery distal to the lesion is the first broadly accepted surgery for coronary artery disease (CAD). The procedure was initially performed off-pump, because cardiopulmonary bypass (CPB) was not available.[1] Off-pump coronary artery bypass (OPCAB) surgery was first performed and reported in the 1960s.[2-4] Most surgeons started preferring to do CABG using CPB after the development of CPB and cardioplegia.[5]

The use of OPCAB technique continued despite the controversy surrounding the long-term graft patency rates, which have been shown to be better following on-pump CABG.[1,2,6] The performance of CABG using the off-pump technique regained momentum in the 1980s, and it was mostly favoured in centres with resource limitations.[4,5] OPCAB provides the potential benefits associated with the avoidance of CPB, which includes reduction of systemic inflammatory response, coagulopathy[4,5,7,8], renal dysfunction and cerebral impairment.[2,5,7] The refinement of surgical techniques as well as the creation of better cardiac stabilising retractors has made OPCAB an established procedure,[5] which has shown to produce favourable outcomes, especially in high risk patients.[2,4,7]

Surgical technique

There are two surgical approaches through which OPCAB is achieved. Minimally invasive-access coronary artery bypass (MIDCAB), where a small left anterior thoracotomy is performed allowing for the anastomosis of the left internal mammary artery to the left anterior descending coronary artery. This technique is no longer used as it allows for only one vessel to be grafted. The other disadvantage to this technique is that the pain following thoracotomy is usually more severe than post sternotomy.[4,5]

The second technique used for OPCAB, is the grafting of multiple vessels through a median sternotomy. This procedure permits mammary artery harvesting and allows access to all the coronaries.[3-5] OPCAB requires effective cardiac wall stabilisation for suturing of the anastomosis. The surgeon uses various strategies to manipulate the heart for adequate exposure. This includes the use of a tissue stabiliser device to access the anastomotic site and cardiac displacement by using deep pericardial retraction sutures to allow exposure of the posterior, lateral and inferior targets.[4,5] This review will focus on the second technique.

Problems associated with OPCAB

The main problem for the surgeons during OPCAB is obtaining adequate exposure to the site of anastomosis which usually requires heart displacement with resultant compression of the ventricular wall. The second problem is to prevent myocardial ischaemia secondary to coronary blood flow interruption during anastomosis. The anaesthetist must be prepared to deal with severe haemodynamic changes, transient cardiac dysfunction, as well as myocardial ischaemia during the procedure.[4] Haemodynamic instability in OPCAB may be due to cardiac manipulation or myocardial ischaemia during anastomosis.[2,9] A clear plan to convert to CPB should be in place in case of cardiovascular collapse or sustained ventricular fibrillation.[4]

Haemodynamic changes associated with cardiac manipulation

Access to the posterior or lateral walls is not as easily achievable compared to accessing the left anterior descending (LAD) coronary artery, via a median sternotomy. The heart needs to be lifted and twisted out of the pericardial cradle to achieve such access. There are important haemodynamic changes that are associated with such a displacement, which results in increased atrial pressures and a marked reduction of cardiac output.[4]

Different stages of the procedure have varying haemodynamic disturbances. The first disturbance occurs when the heart is tilted vertically, resulting in the atria being situated below the corresponding ventricles, and thus requiring the blood to flow upwards into the ventricles.[4] This results in higher filling pressures in both atria and these increased pressures are much higher than the ventricular end-diastolic pressures.[4,10] As a result, the atrial pressure needs to be maintained higher than normal in order to maintain ventricular filling.[4,11] The atria also enlarge becoming larger than the ventricle.[4,10] This stage of manipulation results in moderate diastolic dysfunction and impaired diastolic filling.[4,12]

The second stage of cardiac manipulation associated with haemodynamic instability is when the stabiliser device used for immobilising the anastomotic area compresses the ventricular wall. This restricts the cardiac motion locally and decreases ventricular lumen. The magnitude of the haemodynamic disturbance depends on the location of the stabiliser device, as well as the degree of the heart dislocation.[4]

The compression of anterior and lateral cardiac walls gives rise to a greater disturbance of the haemodynamic status. This is due to the wider displacement of their walls in systole and diastole, as compared to the posteroinferior and septal walls. The extensive lifting of the heart and lateral wall exposure required for anastomosis of the circumflex artery has profound haemodynamic disturbances compared to the surgery on the LAD artery.[4,10,12]

The surgeon sometimes employs certain techniques in order to gain maximal surgical exposure. Such techniques include the displacement of the heart with gauze pads and/or using tissue stabilising devices. These manoeuvers may result in the right ventricle being squeezed between the pericardium and the left ventricle, resulting in severe haemodynamic compromise.[4]

The third haemodynamic disturbance is associated with the vertical positioning of the heart. This manoeuver results in the primary folding of the intracardiac structures at the atrioventricular groove, which then induces distortions of the mitral and tricuspid annuli. This may result in significant mitral and tricuspid regurgitation.[4]

Intraoperative myocardial ischaemia

The second problem associated with OPCAB surgery is the brief periods of myocardial ischaemia, which occur as a result of cross-clamping the coronary artery to ensure bloodless anastomotic conditions.[4] The degree of ischaemia depends on the collateral vessels available and the percentage of target level stenosis. Terminal vessels produce more ischaemia than collateralised vessels.[4,13] Clamping of the right coronary artery (RCA) results in severe ischaemia. This may lead to severe arrhythmias such as complete atrioventricular (AV) block due to AV node artery blood supply interruption. To prevent this, revascularisation of the RCA is done distally beyond its bifurcation.[4,14]

Management of intraoperative myocardial ischaemia

There are different techniques that can be employed to reduce the adverse effects of coronary blood flow interruption during OPCAB surgery:

- Improvement of myocardial oxygen balance
- Ischaemic preconditioning
- Pharmacological preconditioning
- Pharmacological prophylaxis
- Surgical shunting.[4]

Improvement of myocardial oxygen balance

Increasing myocardial oxygen supply and reducing demand/consumption can improve myocardial oxygen balance. Oxygen consumption is achieved by lowering the heart rate and contractility, and can be achieved through pharmacological agents such as beta-blockers and calcium antagonists. Myocardial oxygen supply is achieved by maintaining an adequate coronary perfusion pressure (CPP). The aortic diastolic pressure is the driving pressure for coronary blood flow. CPP can be estimated clinically by measuring the mean arterial pressure (MAP).[4]

A MAP of < 65 mmHG or a CPP of < 50 mmHG during anaesthesia has been shown to be associated with intraoperative ischaemia.[4,15] A MAP ≥ 70 mmHG is recommended to maintain the CPP above the levels associated with intraoperative ischaemia. These levels can be achieved with the administration of a vasopressor like phenylephrine.[4]

Ischaemic preconditioning

OPCAB surgery is associated with a period of unavoidable myocardial ischaemia, during cross clamping of the coronary artery to ensure bloodless surgical conditions for anastomosis. Brief periods of ischaemia followed by reperfusion, thus ischaemic preconditioning, protects the myocardium during periods of obligatory ischaemia.[4]

Pharmacological preconditioning

As an alternative to ischaemic preconditioning, a similar myocardial protection can be achieved pharmacologically. This method of preconditioning is preferable for high-risk patients where ischaemic preconditioning may further worsen the diseased myocardium. Volatile anaesthetics such as isoflurane or sevoflurane are used for this purpose. When administered 30 minutes before the ischaemic insult, at a 2 minimum alveolar concentration (MAC), they activate a preconditioning-like mechanism, which protects the myocardium against ischaemia.[4]

Pharmacological prophylaxis

- Beta-blockers: perioperative use of beta-blocking agents is effective against prevention of perioperative ischaemia in patients with coronary artery disease. The treatment is maintained preoperatively and included in the premedication. A short-acting selective beta 1 blocker like esmolol is very efficient in lowering excessive increases in heart rate.[4]
- Calcium antagonists: use of calcium antagonists such as diltiazem intraoperatively, offers additional benefits to the decrease in heart rate achieved with beta-blockers. This includes the induction of vasodilation in arterial conduits, as well as the prevention of post-ischaemic lesions associated with the increase in intracellular free calcium.[4,16]
- Magnesium ions: the use of magnesium ions during cardiac surgery decreases the incidence of atrial tachycardia.[4]

Surgical shunting

A small shunt inserted into the coronary artery by the surgeon during anastomosis to decrease ischaemic time allows some blood flow and it is sufficient to prevent segmental wall motion abnormalities.[4,17] Intracoronary shunts prevent ischaemia during coronary artery grafting and provide satisfactory graft patency.[18]

Perioperative management

The goals of management in OPCAB include:

- Safe induction and maintenance of anaesthesia using a technique that ensures maximum cardiac protection
- Maintenance of haemodynamic stability
- Early emergence and ambulation.[5,7]

Anaesthetic techniques using high dose opioids together with volatile agents are frequently used during OPCAB surgery.[4,5,7] Some institutions combine general anaesthesia with regional techniques, like thoracic epidural. The advantages of thoracic epidural include dilation of epicardial arteries and a reduction of myocardial oxygen demand, as well as provision of good postoperative analgesia. However, the use of epidural techniques have not shown improved outcome in terms of myocardial performance.[7] Techniques resulting in extubation in the operating theatre have not shown to be cost-effective nor demonstrate additional benefit.[5,7]

Preoperative assessment

A preoperative assessment includes a careful history taking and examination to determine the presence of risk factors associated with increased perioperative morbidity and mortality. The severity and the location of the lesions as well as the surgical plan should be discussed with the surgeon. [2]

Premedication and monitoring

Adequate premedication administered an hour before surgery can reduce the patient's anxiety. This can be achieved with the use of intermediate acting benzodiazepines, like temazepam (0.5-1 mg/kg per os).[2]

Monitoring during OPCAB includes:

- Conventional 5-lead ECG with automated ST-segment analysis: careful consideration should be given to the fact that heart manipulation modifies positional relationships of the heart to electrodes, therefore altering the shape of the tracing and reducing the amplitude of the signal. For adequate monitoring, after each change in heart position a new baseline must be established, so that the observed ECG changes can be correctly interpreted. [4]
- Invasive arterial pressure monitoring: to ensure adequate blood pressure monitoring[2,4]
- Pulse oximetry[2]
- Temperature: oesophageal and rectal[2,4]
- Transoesophageal echocardiography[2,4]

Operating room readiness

- CPB machine and perfusionist ready for a quick setup
- Theatre temperature set at 24°C
- Warming pad/mattress
- Forced air warming device
- Fluid warmer.[2,4]

Anaesthetic technique

- Induction: fentanyl 2–4 mcg/kg, propofol 1–2 mg/kg, rocuronium 0.6 mg/kg.[2]
- Anaesthesia maintenance: isoflurane (1–1.5%) or sevoflurane (1.5–2.5%) throughout operation.[4]
- Fluid management: crystalloids and colloids as required, blood transfusion trigger: 8 g/dl. Use of cell saver.[4]
- Haemodynamic management: maintain an optimal myocardial oxygen balance by keeping myocardial oxygen consumption low, keep MAP > 70 mm HG with an increased preload and vasopressor infusion. Increase leg elevation and fluid administration to correct hypotension associated with tilting the heart into a new position. Treat excessive heart rate increases with a beta-blocker, for example esmolol.[4]
- Anticoagulation: the targeted activated clotting time (ACT) is kept at 250–300 s for OPCAB, because CPB is not used. Heparin 1–2 mg/kg (100–200 IU/kg) is administered to achieve the required ACT, and the ACT is repeated every 30 minutes and heparin is added if necessary. Heparin reversal with protamine is optional.[4]
- Reperfusion and post-graft evaluation: the ischaemic changes observed intraoperatively on the ECG usually disappear after reperfusion; however new RWMA seen on TEE may be associated with myocardial stunning or reperfusion injury. Correction of electrolyte abnormalities, for example potassium and magnesium, is important to avoid life-threatening reperfusion arrhythmias. Ultrasound Doppler flow is used to evaluate graft patency.[2]
- Extubation and postoperative course: the majority of patients post OPCAB can be considered for early extubation unless there were intraoperative and postoperative complications prohibiting such. The extubation criteria include an awake, warm, pain free and haemodynamically stable patient.[2]

Indications for converting to CPB

"Persistence of the following for > 15 minutes despite aggressive therapy:

- Cardiac index < 1.5 L/min/m^2
- S_{vo2} < 60%
- MAP < 50 mm HG
- ST-segment elevation > 2 mV
- Large new wall motion abnormalities or collapse of LV function assessed by TOE
- Sustained malignant arrhythmias".[4]

Conclusion

OPCAB presents a challenging task to anaesthetists. Knowledge of the haemodynamic changes associated with the procedure is important for a successful management of OPCAB surgery.

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