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Anesthesia For Off-pump Coronary Artery Bypass Surgery

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Abstract

NOTE TO THE READER

This article is a descriptive summary of anesthetic techniques for off-pump coronary artery bypass (OPCAB) surgery. We describe our management strategies in order to assist our colleagues who may be encountering OPCAB surgery for the first time, or who are interested in different perspectives on management. This article is not intended to be a dogmatic approach to the topic, but rather, to suggest management strategies in these challenging cases.

INTRODUCTION

The anesthetic management for off-pump coronary artery bypass surgery is particularly demanding and requires an approach specifically tailored to the procedure. OPCAB cases require vigilant anticipation of surgical steps, skilled hemodynamic management and close communication with the cardiothoracic surgeon. Furthermore, optimal management in OPCAB surgery involves a considerable learning curve, for the surgeon, the anesthesiologist and the entire cardiac team. We present our experience in the anesthetic management of over 350 cases involving four different surgeons and twelve anesthesiologists at our two institutions.

This article will present a brief description of OPCAB surgery along with some historical references. Following this is a summary of the advantages of OPCAB over the traditional on-pump coronary artery bypass grafting (CABG) procedure, with pertinent references to the growing literature. Next, the various anesthetic considerations and techniques will be described in some detail, with references to the OPCAB procedure, as it is relevant. We expect that these particular techniques will be modified to fit the experience of individual clinicians, and we anticipate that the anesthetic management of these cases will evolve over time.

OPCAB PROCEDURE

Aortocoronary bypass without the use of cardiopulmonary bypass (CPB) was first performed by Kolesov ([1]) in 1964. Others subsequently reported on the technique, ([2,3,4,5]) but it was largely abandoned with the widespread adoption of cardiopulmonary bypass (CPB) and cardioplegic arrest. Surgery on the beating heart re-emerged with the introduction of so-called “minimally invasive” procedures. These surgeries, such as the minimally invasive direct coronary artery bypass (MIDCAB), are usually performed using limited parasternal incisions, special devices to provide exposure and stabilize the epicardium, and most often a one or two vessel bypass on a beating heart, without the use of CPB. ([6,7]) However, the use of MIDCAB surgery is limited because it does not readily allow for the performance of multiple vessel bypass.

The OPCAB procedure is a natural extension of the more limited MIDCAB surgery and is gaining in popularity with the development of devices to better stabilize the beating heart. The key surgical features of OPCAB surgery are the absence of CPB, operation on a beating heart, use of an epicardial stabilizer, temporary interruption of coronary blood flow during microsurgical anastamosis of distal vessels, and extubation either in the operating room or shortly thereafter. Rather than a single (or at most three) vessel bypass, which would characterize a MIDCAB, our surgeons have been bypassing as many as seven vessels during OPCAB.

ADVANTAGES OF OPCAB

The key advantage of OPCAB surgery is avoidance of “the pump.” This fact alone has numerous ramifications and has been essential in popularizing both MIDCAB and OPCAB procedures.

In terms of morbidity and mortality, the clearest advantage of OPCAB is that the neuropsychologic impairment associated with CPB may be significantly reduced. Numerous recent OPCAB studies report fewer than 1% severe neurologic deficits, such as completed strokes and coma. ([8,9,10]) This compares with incidences of 2-3% for CABG surgery, depending on preoperative risk factors. ([11,12,13]) In addition, we have observed a decrease in minor neurologic disturbances, most notably persistent confusion, after OPCAB surgery. Most off-pump patients are clearly more alert, and many of them are ready to sit up and take liquids a few hours postoperatively.

While OPCAB involves periods of transient coronary ischemia, this procedure avoids the potential global myocardial ischemia that may be associated with CPB. Studies measuring troponin I levels, a specific marker of myocardial damage, report that OPCAB surgery is associated with significantly less release of the protein. ([14,15,16]). We have found, in agreement with published reports, that fewer inotropes are needed after the revascularization, there are fewer dysrhythmias (especially atrial fibrillation) and there is less need for post-procedure cardiac pacing. (8, 10, [17])

In providing anesthesia for OPCAB, we have experienced far fewer problems with hemostasis and perioperative bleeding. Use of a lower dose of heparin, lack of CPB-associated hemodilution, and absence of pump-related platelet dysfunction have a significant effect on perioperative blood loss. The use of prophylactic antifibrinolytics, such as aminocaproic acid and aprotinin, is largely unnecessary. At our institutions, the transfusion of heterologous blood has been reduced nearly by one-half, in agreement with several published reports. ([9], 17,[18])

Avoiding extracorporeal circulation confers a number of other advantages. Respiratory problems are reduced, and even patients with fairly severe COPD are being extubated shortly after the procedure. Renal function is better preserved with OPCAB, as demonstrated by fewer instances of postoperative renal insufficiency. (14, 17) Pharmacokinetics are more predictable since there is no uptake of drug from the pump, and there are fewer metabolic perturbations, especially in glucose, potassium and calcium. Lastly, OPCAB avoids complement activation and the systemic inflammatory response associated with CPB, ([19, 20]) which may facilitate postoperative analgesia and fluid management.

PREOPERATIVE CONSIDERATIONS

Since early awakening and extubation is an anesthetic goal in OPCAB surgery, preoperative sedation should not be heavy. We use relatively small doses of benzodiazepines preoperatively and supplement with intravenous midazolam and fentanyl in the operating room and during placement of invasive lines.

To help maintain normothermia, we assure that our OPCAB patients are warm preoperatively, even if active warming is necessary. Once in the operating room, the patient is placed on a circulating-water mattress and then covered with a forced-air warming blanket (BairHugger, WarmAir). All rapidly infusing intravenous fluids are warmed. Using these measures, we have not found it necessary to raise the ambient room temperature. This emphasis on maintaining normothermia may facilitate hemodynamic management and expedite tracheal extubation shortly after the case. ([21])

As with all cardiac cases, large-bore intravenous access and central access to the circulation is necessary. Because these cases often involve unstable hemodynamics, especially during distal anastamoses, ready access to the central circulation is essential for both bolus dosing and infusions.

Our use of monitoring for OPCAB cases has evolved over time. ST-segment analysis has been particularly useful, especially in assessing the tolerance of the heart for coronary occlusion during the distal anastamoses. A non-invasive BP cuff is used to back up and verify the arterial tracing. The plethysmograph on the pulse oximeter is very helpful in assuring adequate perfusion.

While a pulmonary artery catheter may not be warranted on the basis of a patient's cardiac status, we have found that preoperative ventricular function does not adequately predict any patient's response to heart positioning and coronary occlusion. Accordingly, it is our current practice that all OPCAB patients are monitored with pulmonary artery catheterization and themodilution cardiac outputs.

The use of transesophageal echocardiography (TEE) is limited in OPCAB cases by the difficulty in obtaining useful information while the heart is retracted for many of the distal anastamoses. With the use of frequent cardiac output monitoring, we have found that the TEE has not changed overall management to any significant degree.

INDUCTION AND INITIAL MAINTENANCE

Because hemodynamic changes occur rapidly and unexpectedly in OPCAB surgery, we routinely have a vasodilator and vasopressor/inotrope ready for immediate infusion. The choice of these drugs has evolved over time. While nitroglycerin is used universally for vasodilation, the selection of vasopressor remains varied, the most common choices being phenylephrine, norepinephrine and dopamine. Likewise, it is useful to have a number of vasoactive medications readily available for bolus administration. The medications we have found most helpful are ephedrine, phenylephrine (40-100 mcg/ml), epinephrine (10 & 100 mcg/ml), calcium and lidocaine.

The induction of anesthesia is determined by the patient's status at the time and the aim to extubate the trachea at the end of the case. Etomidate or propofol are most often used for induction, along with a loading dose of opioid. For most patients a fentanyl dose of 7.5 to 10 mcg/kg (or sufentanil 0.5-1.0 mcg/kg) has been adequate to help blunt the surgical stimulus of incision and sternotomy, yet also allow for timely tracheal extubation. Anesthesia is maintained using a volatile agent, and occasionally, a propofol infusion is also used. Any of the intermediate-acting neuromuscular blockers adequately provide muscle relaxation, while also being readily reversible.

The heparin dose we use for OPCAB is 1.5-2 mg/kg, aiming to keep the activated clotting time (ACT) greater than 300 seconds during vessel anastamoses. Reports of systemic anticoagulation vary considerably in the literature, with heparin doses varying between 1 and 3 mg/kg, and ACTs usually targeted in the 200-300 range. (17, [22], [23]) While we initially checked the ACT every 20 minutes, we have found that less frequent measurements are reasonable.

We have found it to be advantageous to keep the patient well hydrated for OPCAB surgery, a practice differing from that in CPB cases where we attempt to minimize fluid administration. Generous hydration, guided by the pulmonary artery catheter, helps alleviate the reduction in preload that occurs when the heart is retracted, thereby aiding hemodynamic management. It may also help reduce oliguria during this period.

After procurement of saphenous vein and skin closure, we place a sterile forced-air warmer at the highest setting over the lower part of the body. This has made a significant difference in assuring normothermia during the remainder of the procedure.

To prevent dysrrhythmias during manipulation of the heart and coronary occlusion, we routinely give prophylactic doses of bolus lidocaine (1-1.5 mg/kg) and infused magnesium (2 gm) prior to the first distal anastamosis. ([24]) We have a low threshold for running a lidocaine infusion (2-3 mg/min) and use it routinely for right coronary artery grafting. If nitroglycerin is not already infusing, a nitroglycerin infusion is usually started prior to suturing the distal anastamoses and is most often continued throughout the procedure. In patients with serum potassium less than 4.0, we routinely infuse potassium during this period. ([25]) Lastly, a pacemaker is readily available in case pacing on the field is required, especially to treat bradyarrhythmias associated with the right coronary artery anastamosis.

We are always prepared to adjust management and maintain hemodynamics for a semi-elective or more emergent conversion to CPB. As surgical experience has grown with OPCAB, there have been fewer cases where this was necessary.

ANASTAMOSES

The suturing of the distal anastamoses is by far the most demanding part of the case. The anesthesiologist must be continually observing the field, watching the monitors and communicating with the surgeon.

Once the surgeon chooses the first vessel for the distal anastamosis, he places a silastic tape around it to produce proximal coronary occlusion. If this is reasonably well tolerated, he then places the epicardial stabilizing device. Once this is in position, he incises the target site and starts the distal anastamosis.

During this period of distal anastamosis, there is no "turning back". The consequences of this temporary coronary occlusion may be relatively insignificant or may lead to severe heart failure and ultimately cardiac arrest. It is helpful to measure serial cardiac outputs during this period to help determine the need for resuscitative efforts. In our experience, cardiac indexes have been as low as 0.7 L/min/m2 during this period. In addition, the ST segments may become severely elevated or depressed.

The key to anesthetic management during a distal anastamosis is to aggressively maintain hemodynamic stability. In patients where preoperative cardiac function is impaired, we often use a background infusion of phenylephrine, dopamine or norepinephrine to maintain blood pressure and cardiac output. Infusion of an inotrope is also helpful if cardiac output falls significantly after application of the epicardial stabilizer. If the cardiac index continues to fall during the anastamosis (e.g., CI<1.5), bolus doses of epinephrine (10-20 mcg) are given immediately to avoid progressive cardiac failure. Maintenance of cardiac output appears to be more important than maintaining systemic blood pressure. Proactive and assertive treatment of this ischemia-induced ventricular dysfunction is essential to success during this stressful phase of the surgery.

We monitor arterial blood gases frequently during the distal anastamoses. Metabolic acidosis is treated with sodium bicarbonate to keep the corrected pH greater than 7.30. We have found that with a more physiologic pH it is easier to maintain hemodynamic stability.

To optimize surgical exposure during a distal anastamosis, the anesthesiologist may need to hand ventilate or even stop ventilating for short intervals. This would be most likely, for example, during the anastamosis to a marginal branch of the left circumflex artery. It may be necessary to subsequently reexpand the lungs and hyperventilate to prevent patchy atelectasis and hypercarbia.

Once the anastamosis is complete, the silastic tape is removed, coronary flow is reestablished and both cardiac index and ST segment changes should improve. Assessment of cardiovascular status during this "rest period" will help determine when the next vessel may be approached. Blood pressure and cardiac output should return to near baseline levels before the surgeon attempts the next anastamosis, especially if it involves displacement of the heart. At times the anesthesiologist may need to interrupt the surgeon's progress to allow the heart to recover from a poorly tolerated period of coronary occlusion.

Subsequent distal anastomoses are carried out in a similar manner. For certain target sites, such as the branches of the circumflex artery, deep pericardial retractors or a sling may be used to retract the heart into an optimal position for the surgical approach. This displacement of the heart, with the apex pointing anteriorly, causes right ventricular dysfunction and resultant biventricular pump failure. This deterioration in circulatory status is due primarily to a severe reduction in stroke volume, as the geometrically distorted right ventricle cannot sufficiently expand during diastole. ([26]) During this retraction phase, the ECG tracing is characteristically flat and both rhythm and ST analysis are often indiscernible. If a TEE is being used, its images of the retracted heart provide little useful information. Fortunately, cardiac output measurements are still possible and plethysmography is often a reassuring guide of peripheral perfusion.

To improve the circulatory status during heart displacement, the patient is placed in approximately 20-degree Trendelenburg position. As a practical point, we use special positioners to keep the patient from shifting on the operating room table. Steep Trendelenburg position causes decreases in pulmonary compliance and functional residual capacity and may compromise adequate ventilation, especially in obese patients.

Once the "last distal" is in place, the surgeon is ready to apply a partial cross clamp to the aorta for placement of the proximal anastamoses. This step requires a rapid lowering of blood pressure, usually with volatile agent, nitroglycerin, or nitroprusside. The following period of relative calm allows the heart to recover from the repeated insults and the anesthesiologist to prepare for closure and emergence.

EMERGENCE, EXTUBATION, POSTOP ANALGESIA

Once the heart is reperfused with the multiple bypass grafts, we administer protamine to reverse anticoagulation. Heparin reversal is somewhat controversial and is omitted in some programs. (23, [27]) If the surgeon chooses to perform parasternal intercostal nerve blocks, they are done at this point. After the sternum is reapproximated, the muscle relaxant is reversed and cell saver blood is returned.

To be eligible for extubation in the OR, the patient must be awake, normothermic, non-acidotic and adequately ventilating. If the patient is not ready to be extubated in the OR, he may usually be extubated a short time later in the intensive care unit.

A key to success here is adequate analgesia. Unless contraindicated, we routinely give ketorolac (Toradol) to OPCAB patients prior to extubation. Additionally, intravenous opioids are titrated to effect. We have also used patient-controlled analgesia with considerable acceptance.

At one of our institutions, intrathecal morphine has been used for postoperative analgesia. For patients without coagulation abnormalities, preservative-free morphine (0.2-0.4 mg) is instilled into the subarachnoid space at the lumbar level. This is usually done in the operating room just prior to placement of invasive lines, but it has also been done during the postoperative period. Despite reports of prolonged ventilatory depression and inadequate analgesia in CABG patients, ([28]) in our situation intrathecal morphine has been well accepted, safe and effective, with minimal side effects.

Our experience with recovering OPCAB patients in the ICU has been one of slow, but gradual acceptance by both nurses and respiratory therapists. While our ICU nurses have been accustomed to receiving anesthetized, intubated cardiac patients, OPCAB patients often arrive extubated and may be restless and complaining of pain. Nurses caring for these patients must be skilled in pain management as well as in handling various airway problems. For them, management of inotropic support and measurement of chest tube output has been replaced with placement of nasopharygeal airways, titration of morphine and reassurance of the temporarily disoriented patient.

Similarly, respiratory therapists accustomed to ventilator management are most often called upon to provide enriched oxygenation, bronchodilator treatment and early chest physiotherapy. With experience, we have eliminated routine "ventilator set-up" but we still insist on having a respiratory therapist readily available.

CONCLUSION

OPCAB surgery is a significant advance in the operative treatment of coronary artery disease and presents significant challenges for the anesthesiologist. A number of aspects such as careful preparation, appropriate monitoring, maintenance of normothermia, specifically tailored drug management, maintenance of hemodynamic stability, provision of good operating conditions and a goal of early extubation are important in the management of these cases. As both surgical and anesthetic expertise with OPCAB surgery grows, we will make further progress toward anesthetic management that provides the optimum of safety and comfort to our patients.

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