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# Anesthesia for off-pump coronary artery bypass graft (OPCABG) surgery: Experience at the Montreal Heart Institute

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**Since the recent development of effective devices for target vessel exposure and stabilization, off-pump coronary artery bypass graft (OPCABG) surgery has gained widespread use as an alternative to conventional on-pump CABG. OPCABG has several advantages (Table 1); however, in a recent multicentre, randomized trial, Nathoe et al reported that in low-risk patients, there was no difference in cardiac outcome at 1 year between those who underwent OPCABG and those who underwent CABG.[1] On the other hand, OPCABG was found to be more cost-effective. The same authors also reported decreased creatine kinase (CK)-MB release, reduced use of blood products, and shorter hospital stay following OPCABG.[2] This issue of *Anesthesiology Rounds* reviews our current understanding and experience with OPCABG at the Montreal Heart Institute and discusses its practical aspects. For more details, the reader is referred to several reviews on the subject.[3-5]**

## ANESTHESIA MANAGEMENT

### *Preoperative period*

The preoperative evaluation of patients undergoing OPCABG does not differ from the routine preoperative evaluation of patients undergoing major surgery. It is important to identify health problems associated with coronary artery disease (CAD) that may have an impact on anesthesia management. Special attention should be paid to the number of vessels affected, and the location and severity of the stenosis, in anticipation of hemodynamic changes that may occur with surgery.

Current cardiac medications (with the exception of diuretics) are prescribed on the morning of surgery. Whether angiotensin-converting enzyme (ACE) inhibitors or angiotensin II receptor antagonists (ARA) are used or withheld on the morning of surgery is controversial. A possible link between these drugs and persistent hypotension after anesthesia induction and during cardiopulmonary bypass (CPB), has led some authors to strongly recommend omitting them on the day of surgery.[6] Although no study has been published that has focused on OPCABG patients, it is our practice to refrain from giving such drugs on the morning of surgery.

### *Premedication*

Premedication aims to alleviate anxiety and its adverse effects (eg, hypertension and angina), enabling patients to be more comfortable during the placement of intravascular catheters. A combination of a narcotic (morphine 0.1-0.15 mg/kg IM) and a sedative (scopolamine 5 µg/kg IM or midazolam 0.05 mg/kg IM) is commonly administered. In unstable or debilitated patients, the premedication dose is reduced or omitted. Supple-



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**TABLE 1: Reported advantages of OPCABG**

**Mortality and morbidity**
- Overall cardiac outcome at 1 year: no difference (RCT)[1]
- Reduced morbidity in high-risk elderly patients (>80 years-old) (R)[24]
- Reduced operative mortality in elderly patients (>80 years-old) (R)[25]

**Myocardial function**
- CK-MB release is lower for OPCABG (RCT)[2]
- Variable graft patency rate: lower at 3 months[26] versus no differences (RCT)[27]

**Neurological function**
- Improved cognitive outcome at 3 months (RCT)[28]
- Lower incidence of stroke in high-risk patients (R)[29]
- Reduced stroke in elderly patients (>80 years-old) (R)[25]

**Hematologic**
- Reduction in the use of blood products (RCT)[2]

**Economic and other advantages**
- Lower costs for OPCABG (RCT)[2,27]
- Reduced inflammation: limited to a few hours after surgery (Review)[30]

RCT = randomized controlled trial; R = retrospective analysis

mental oxygen is delivered after the patient has been premedicated to avoid arterial oxygen desaturation.

### *Intraoperative period*

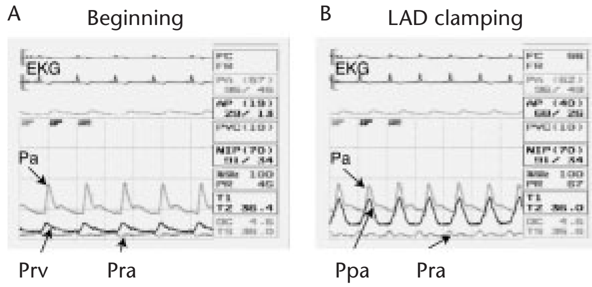
Meticulous attention to fluid replacement, monitoring, treatment of hemodynamic instability, and prevention of hypothermia is important during an OPCABG operation and crucial to the success of the procedure. Unfractionated heparin (UFH) 100 µg/kg is administered before starting anastomosis. The goal is to prevent intracoronary thrombus formation when manipulating the vessel. Should prompt institution of CPB be necessary, supplemental UFH is administered (to a total dose of 300 µg/kg). In OPCABG cases, UFH therapy is monitored by measuring activated clotting time (ACT) every 30 minutes. An arbitrary goal for ACT is between 300 and 400 seconds.

To decrease myocardial dysfunction in each coronary artery territory, the surgical strategy is to start with the dominant lesion. This vessel is normally the most collateralized and, consequently, less likely to induce myocardial ischemia.

### *Monitoring of the OPCABG patient*

At the Montreal Heart Institute, patients undergoing OPCABG are generally monitored with an ST-segment analysis system, a radial artery catheter, and a pulmonary artery catheter. Infrared brain oxymetry (Invos, Somanetic) and continuous right ventricular pressure monitoring have been recently introduced

**FIGURE 1: Acute pulmonary hypertension and hemodynamic instability in a 70-year-old man during left anterior descending artery (LAD) clamping.**
(A) Baseline tracing.
(B) Pulmonary hypertension was secondary to ischemic mitral regurgitation confirmed by TEE. The procedure was cancelled and the patient had coronary revascularization under CPB.




EKG = electrocardiogram; Pa = arterial pressure;
Ppa = pulmonary artery pressure; Pra = right atrial pressure

(Figure 1). Our experience with transesophageal echocardiography (TEE) during cardiac surgery has been reported in a study by Couture et al.[7] TEE is mainly reserved for patients at risk of hemodynamic instability (ie, patients with severe myocardial systolic and diastolic dysfunction, with mild-to-moderate mitral regurgitation) or for those who develop hemodynamic instability during the procedure. Hemodynamic instability during OPCABG can be secondary to several factors (Table 2).

### *Prevention of hypothermia*

Care must be taken to prevent hypothermia, particularly if early extubation is planned. The adverse effects of hypothermia on wound healing, coagulation, and dysrhythmias are known.[8,9] Prevention of hypothermia requires a combination of various measures. Since heat loss is proportional to the period of time that the anesthetized patient is left exposed, this interval should be reduced to a minimum. Operating room temperature is set at 21º C and a heating mattress set at 40º C is placed under the patient. A fluid warmer is used for intravenous solutions; surgical irrigating solutions are also warmed. Respiratory heat losses related to warming and humidification of inspired gases can be reduced by a low gas flow and by placing a heat and moisture exchanger on the endotracheal tube. Finally, a forced-air warming blanket is sometimes placed over the patient's head and shoulders.

### *Induction of anesthesia*

The aim of the anesthetic regimen is to be compatible with the goal of early extubation; therefore, drugs with a short or intermediate duration of action

**TABLE 2: Etiologies of hemodynamic instability observed during OPCABG surgery at the Montreal Heart Institute from 1999 to 2004.**

- Myocardial ischemia with pulmonary hypertension
- Cardiac compression
- Ischemic mitral regurgitation
- Acute tricuspid regurgitation from pulmonary hypertension
- Left ventricular diastolic dysfunction
- Right ventricular diastolic dysfunction
- Right ventricular outflow tract obstruction
- Aortic dissection

are chosen. There is little reason to choose one drug combination over another as long as the goals of hypnosis, analgesia, amnesia, autonomic stability, and neuromuscular blockade are achieved in a manner that is compatible with early extubation. Several narcotics reduce the response to intubation and the pain associated with surgical procedures, including fentanyl (15-50 μg/kg) or sufentanil (1.5-3.0 μg/kg). Remifentanil is a potent, ultra-short-acting narcotic that can also be given (infusion rates of 0.15-0.4 μg/kg/min). Unconsciousness can be induced with one of the following: thiopental (2-3 mg/kg), midazolam (0.1-0.2 mg/kg), or propofol (1-2 mg/kg). In addition to one of the above-mentioned narcotics, anesthesia is maintained with a propofol infusion or an inhalation agent (eg, isoflurane or sevoflurane). Inhalation agents are of particular interest by virtue of their association with ischemic preconditioning.

Neuromuscular-blocking drugs with a medium duration of action include rocuronium, vecuronium, or cisatracurium. Pancuronium is associated with longer recovery time, delayed extubation, and is not recommended for fast-track cardiac surgery.[10]

During the period between anesthesia induction and the start of coronary anastomosis, 2-5 g of magnesium sulfate can be given. It has been suggested that preoperative magnesium reduces the incidence of atrial tachyarrhythmias in the postoperative period.[11] Furthermore, hypomagnesemia is commonly observed in the perioperative period in our patient population. Magnesium also decreases arterial graft spasm.[12] Magnesium supplementation rarely causes hypotension when administered slowly, but it prolongs the duration of neuromuscular-blocking drugs; therefore, dosing must be adjusted accordingly.[13]

### *Blood salvaging strategies*

OPCABG surgery is associated with decreased transfusion requirements,[14] particularly in the postoperative period, and most studies report intraoperative blood-loss values similar to those for CABG surgery. Avoiding CPB eliminates dilutional anemias related to pump priming. In addition, OPCABG causes fewer inflammatory and hemostatic changes than CABG with CPB, leading to fewer coagulation abnormalities and less bleeding in the immediate postoperative period. Although meticulous surgical hemostasis is paramount, along with heparin reversal, techniques are available to reduce autologous blood product use. For example, normovolemic hemodilution consists of removing whole blood and replacing it with crystalloid or colloid solutions when the initial hematocrit level allows. A cell saver can also be used. This device collects shed blood through heparinized suction and, after washing and centrifugation, provides concentrated recovered red cells that can be returned to the patient. However, the usual operative blood loss of 300-500 cc during OPCABG is too modest to make blood reinfusion worthwhile.

### *Fluid replacement*

Continuous fluid replacement throughout the operation is necessary to maintain preload, since it is not uncommon for a patient to be relatively hypovolemic at the completion of OPCABG surgery. This can often be explained by underestimation of insensible fluid loss and peripheral vasodilatation secondary to the inflammatory response. Insensible losses occur through an open thorax and are in the order of 6-8 cc/kg/hr.[15] Apart from the monitoring techniques mentioned above, diuresis of 0.5-1.0 cc/kg/hr is a good reflection of volume status and renal blood flow.

### *In the immediate postoperative period*

The current trend is towards early extubation after cardiac surgery or so-called “fast-tracking.” With early extubation, patients are mobilized sooner, discharged more quickly from the intensive care unit (ICU), and the total cost may be reduced by up to 25%.[16] The endotracheal tube is removed once the usual criteria are met (ie, the patient is awake and the airway is protected, and he/she is hemodynamically stable with minimal inotropic support, has acceptable mediastinal bleeding, and has adequate gas exchange).

### *Postoperative analgesia*

Early extubation and fast-tracking rely on adequate postoperative analgesia. This is best achieved with a multimodal approach, in which benefits are drawn from each class of drug while minimizing dose-related side effects. The cornerstone of pain relief is the opioid class of drugs. Morphine (2-4 mg/hr) and fentanyl (25-75 µg/hr) are commonly administered intravenously, either as an infusion or via a patient-controlled analgesia device. If oral medication is tolerated, hydromorphone or an acetaminophen-codeine combination is an acceptable alternative.

Nonsteroidal anti-inflammatory drugs (NSAIDs) are good co-analgesics with a significant opioid-sparing effect.[17] They are often omitted in the immediate postoperative period because of possible side effects that include platelet dysfunction, renal impairment, and gastrointestinal tract bleeding.

Neuraxial analgesia, either spinal or epidural, is another approach to postoperative pain management. The advantages of profound analgesia (eg, little respiratory depression, attenuation of the stress response, and decreased sympathetic tone) are appealing. Cheng et al reported that 5 µg/kg of intrathecal morphine delivers excellent analgesia, improves pulmonary function tests, and leads to better cognitive function.[18] However, the benefits of the technique must be weighed against the rare, but serious complications of epidural hematoma and spinal cord compromise. Cardiac surgical patients may be at higher risk because of perioperative anticoagulation or exposure to other drugs that have an effect on hemostasis.

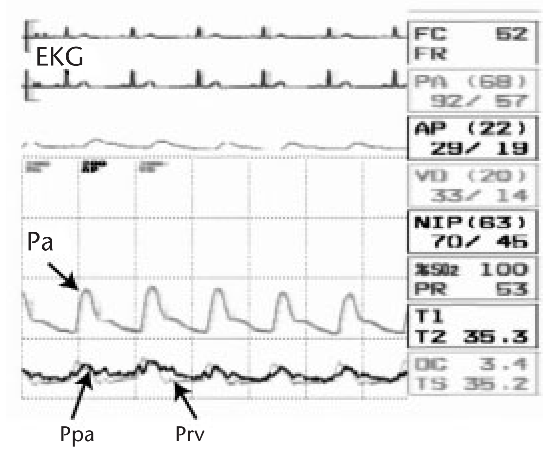
## DIAGNOSIS OF HEMODYNAMIC DERANGEMENTS

Hemodynamic variations in OPCABG may be due to mobilization and stabilization of the heart, or myocardial ischemia occurring during coronary occlusion.[3] Suction and compression-type stabilizers exert hemodynamic effects through different mechanisms. Recent development of apical suction devices – Xpose® (Guidant, Indianapolis, IN), and Starfish® (Medtronic, Minneapolis, MN) – appears to have greatly facilitated access to all parts of the coronary anatomy, with reduced hemodynamic impact. However, there appears to be no difference in hemodynamic values between vacuum and mechanical stabilization.[19] Coronary occlusion during anastomosis can have additional effects on left ventricular (LV) function, depending on the status of collateral flow.

### *Myocardial ischemia*

All methods for monitoring myocardial ischemia have limitations. Electrocardiography

**FIGURE 2: Hemodynamic values with Trendelenburg positioning.** Note the discrepancy between arterial pressure (Pa = 92/57 mm Hg) and non-invasive pressure (70/45 mm Hg). This overestimation of the invasive arterial transducer is a result of the transducer positioning below the heart level. Once the patient is repositioned in dorsal decubitus at 0°, the gradient disappears.




(ECG), the common method for monitoring intraoperative myocardial ischemia during CABG, combines leads II and V5 for diagnosing ST-segment changes.[20] However, during OPCABG, the heart is frequently mobilized, particularly when the circumflex and posterolateral coronary arteries are involved, often resulting in microvoltages in the monitored leads. The value of ECG and ST-segment monitoring under these conditions has not been well-explored.

We found TEE most useful during cardiac manipulations when hypotension is associated with increased filling pressure. In this situation, TEE can help differentiate cardiac dysfunction secondary to myocardial ischemia (when regional wall motion abnormalities are present) from the much more common scenario when increased filling pressure is secondary to extracardiac compression. We have found the 2-dimensional TEE 4- and 2-chamber views to be the most useful.

### *Reduced preload*

Hypotension secondary to hypovolemia is usually associated with decreases in pulmonary artery pressure (PAP) and central venous pressure (CVP). Fluid loading and the Trendelenburg position restore cardiac output (CO) by increasing venous hydrostatic pressure and, subsequently, LV preload. However, in the Trendelenburg position, invasive arterial pressure may overestimate true arterial pressure because of transducer displacement below the cardiac structure (Figure 2). If these maneuvers are ineffective, the administration of phenylephrine or norepinephrine should be considered. TEE can be useful to confirm hypovolemia and fluid responsiveness if the patient remains hypotensive. With the fork-type stabilizer, exposure of the circumflex and posterior descending arteries necessitates verticalization of the heart that may occasionally impede atrial preload by distortion/compression of the right atrium, inferior vena cava, and right ventricular outflow tract (RVOT).

### *Myocardial dysfunction*

**Systolic dysfunction:** Hemodynamic instability related to severe systolic dysfunction is characterized by an increase in PAP and CVP, along with a decrease in CO. TEE monitoring is particularly helpful in differentiating systolic dysfunction associated with regional wall motion abnormalities from cardiac compression where increased filling pressure is secondary to extracardiac compression. TEE may be considered in patients with known preoperative systolic dysfunction or in those who remain hypotensive despite vasoactive agents and inotropic support. **Diastolic dysfunction:** Our group recently raised the issue of evaluating diastolic function during cardiac surgery.[21] We currently employ Doppler to evaluate both left and right diastolic function during OPCABG. This evaluation allows a better understanding of the hemodynamic changes that occur during the procedure.

### *Cardiac compression*

During anterior descending and diagonal artery positioning with the compression-type stabilizer, minimal pressure is applied by the stabilization device to avoid direct compression of the LV outflow tract and consequent abnormal diastolic expansion. This may lead to increases in PAP and CVP. Hemodynamic disturbances during positioning with the Octopus stabilizer are thought to be caused by decreased RV filling and, to a lesser extent, LV filling by direct ventricular compression. Volume loading, the Trendelenburg position, and vasopressor infusion usually correct these derangements, although an RV assist device has been proposed for unstable patients. TEE is indicated in patients who are not responsive to the above treatment and helps differentiate cardiac dysfunction from extracardiac compression.

### *Mitral regurgitation*

In occasional cases, significant acute mitral valve dysfunction can precipitate hemodynamic instability after heart positioning or coronary artery clamping. Patients most at risk of developing severe mitral valve regurgitation are those with pre-existing myocardial dysfunction or mild-to-moderate mitral regurgitation. An increase in PAP and CVP, the presence of a “v” wave, and a regurgitant colour Doppler signal from the mitral valve are key features. In these cases, treatment of ischemic mitral regurgitation consists of intravenous vasodilators and vasoactive drugs to maintain coronary artery perfusion. Transient inferior vena cava clamping can control an acute increase in PAP that is unresponsive to the usual treatments.[22,23] Mitral valve repair or replacement can be considered if dysfunction persists after revascularization and thus, will lead to the cancellation of the OPCABG surgery.

## CONCLUSION

In summary, OPCABG has a definitive role in cardiac revascularization surgery. Numerous advantages have been reported, but the universal use of this approach in surgical revascularization is under debate. Future studies will identify the type of patient who would clearly benefit from OPCABG. A clear understanding of the surgical procedure and the mechanisms of hemodynamic changes are of paramount importance for the anesthesiologist in charge of such patients.

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