Anesthesia Care for Patients Undergoing Total Revascularization Procedure without Using Cardiopulmonary Machine

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Citation

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Abstract

INTRODUCTION

The pioneers of cardiac surgery initially introduced the concept of myocardial revascularization, without the use of cardiopulmonary bypass (CPB). Vinberg attempted to increase the blood flow to the ischemic myocardium by implanting the internal mammary artery in the muscle mass of the left ventricle. [1] Sabiston performed his first coronary bypass by anastomosing the internal mammary to left anterior descending artery without using CPB. [2] However, the development and evolution of extracorporeal circulation techniques produced a motionless and bloodless field which most cardiothoracic surgeons felt was superior for performing coronary bypass grafting. The old concept of myocardial revascularization without CPB has recently gained an increasing interest among cardiac surgeons. Currently, TROPCAB refers to total revascularization by coronary bypass without the utilization of a cardiopulmonary bypass (CPB) machine or off-pump.

CPB is not without systemic complications including stroke, hemorrhage, and renal failure. [3,4,5] Cardiothoracic surgeons have studied ways to try and decrease these devastating problems. The decrease in complications associated with minimally invasive coronary artery bypass through a lateral thoracotomy incision (MIDCAB), was initially thought to be attributed to the type of the surgical incision (thoracotomy vs. sternatomy). [6] Subsequent study has shown that the lack of CPB is the reason for improvement in morbidity and mortality associated with this operation.[7, 8] The incidence of cerebrovascular accident following CABG using the traditional CPB techniques is about 5%. Subtle neurobehavioral changes have been described with a higher frequency following the use of CPB, even in those patients without any clinically detectable neurologic deficits. 3, [9] Off-pump technique has demonstrated better neurologic outcomes both by a decreased stroke rate and also fewer subtle neurobehavioral changes.8 , [10]

Because of the technical difficulties associated with mastering aspects of off-pump CABG, TROPCAB was initially limited to vessels that were easily accessible without extraneous manipulation of the heart. With innovative surgical techniques, and development of new anesthetic paradigms, exposure of the posterior vessels is now possible without harmful hemodynamic derangement. Therefore, theoretically every patient is a candidate for TROPCAB. Anesthesiologists need to be prepared to manipulate hemodynamic parameters in order to provide not only optimal operating conditions for surgeon, but also to assure that the patient is placed in as little risk for postoperative complications as possible. Both the patient and the surgeon believe that decreased tissue insult by cardiopulmonary bypass should translate to early mobilization of the patients from the operating room to home. Decreased need for ventilatory support, intensive care and hospital stay are top priorities for the surgeon while early extubation, reduced need for transfusion, and more efficient pain management are major expectations of the patients. Anesthesiologists need to be prepared to meet these expectations.

MONITORING FOR “OFF-BYPASS”

Like any other operative procedures, vigilant monitoring is the key to successful anesthesia care for these cases. Hemodynamic changes are more dramatic with TROCAB; consequently undivided attention of an anesthesiologist is required. The periods of inactivity and time to prepare for the separation from CPB are not existent. Thus, the anesthetic is even more challenging to give to TROCAB patient than to those having more traditional CPB techniques.

Assuring the adequacy of blood flow to the coronary arteries is the primary concern during CABG surgery and is best monitored with continuous and pulse Doppler wave analysis of the grafts. [11, 12] The anesthesiologist applies standard monitors during CABG surgery that include 2-lead electrocardiogram (II and V5), pulse oximetry, capnogram, temperature, and non-invasive blood pressure measurement. In addition to the standard monitoring, arterial line monitoring is critical in all coronary revascularization procedures, and beat to beat changes in blood pressure are often severe and unpredictable with TROCAB. Measurement of filling pressure (pulmonary artery catheter or central venous catheters) should also be performed, as the trend of changes in these parameters provides useful information.

Many investigators, however, have debated cost effectiveness of routine application of pulmonary artery pressure monitoring. [13,14,15] Introduction of continuous cardiac output monitors has increased the usefulness and reliability of pulmonary artery catheters. [16, 17] These devices provide frequent updates of cardiac function during surgery. It is important to understand that this data is not a "real time" measurement. There is a lag of 30 seconds in displaying mixed venous oxygen saturation and 2 to 6 minute lag for cardiac output measurement. [18] The clinician should be aware of these lags when making clinical decisions.

Trans-esophageal echocardiogram (TEE) provides invaluable information during TROPCAB procedures. Beat to beat visualization of ventricular wall motion is a sensitive index of myocardial well being. [19, 20] TEE may serve as a guide to make decisions regarding volume. Furthermore, functional regurgitation of mitral valve during lifting the heart to revascularize the posteriorly located vessel (e.g., circumflex and obtuse marginal) can be easily detected by TEE monitoring. 20 Application of TEE in some cases may eliminate the use of PA catheters and it can be used along with CVP for complete cardiovascular monitoring usually in-patients with normal left ventricular function. The major disadvantage of TEE is that it requires further expertise and additional personnel to interpret the images beyond the anesthesiologist giving the anesthetic. [21]

The patients undergoing coronary revascularization procedures by definition have an altered state of balance between myocardial oxygen supply and demand. A major goal of the anesthetic should be to improve myocardial oxygen supply while minimizing demand. Key to providing this anesthetic is avoiding tachycardia and hypertension during intubation, skin incision and sternatomy. Adequate anesthesia and analgesia blunts sympathetic response.

BLOOD PRESSURE CONTROL DURING "OFF-BYPASS"

Manipulation of the heart in the presence of coronary artery occlusion causes changes in conduction patterns on the ECG and wall motion abnormalities on TEE. Decreases in cardiac output and mixed venous oxygen saturation are also noted in some patients. However, this may be partially related to myocardial ischemia along with mechanical effects of retraction and stabilization. With the advent of new stabilizing techniques such as the pericardial suspension suture at left superior pulmonary vein and the evolution of new retractors with myocardial stabilizers, it is possible to successfully operate without the need for global myocardial stability and induced profound bradycardia to improve the surgical exposure [22].

The impact of these new techniques on the anesthetic is several fold. With elimination of the need to induce bradycardia, volume dependence is remarkably decreased. However, the lower heart rates are still preferred both by the surgeons and anesthesiologists not only to improve the surgical exposure but also to improve myocardial oxygen demand. Lower heart rates results in dependency of cardiac output to the adequacy of venous return. Placing the patient in trendlenberg position easily attains transient improvement of venous return. This position not only improves the venous return and cardiac output temporarily but also improve the surgical exposure while distal anastomosis is being made on posteriorly located coronary arteries.

Blood pressure control during TROPCAB is very important and should be meticulously regulated by the anesthesiologist. Although the maintenance of tissue perfusion to the heart and other vital organs during the surgical procedure is critical, blood pressure should be deliberately decreased during proximal anastomoses to facilitate partial aortic cross clamping. Hypovolemia and low systemic vascular resistance along with myocardial depression are among the major differential diagnosis of hypotension during TROPCAB procedures. Manipulation of the heart especially when it is associated with bradycardia results in impaired venous return and hypotension. Thus, communication between the surgical and anesthesia teams is critical to avoid life threatening complications and perhaps even cardiac arrest.

In order to replenish the venous return to the heart, as previously mentioned changing the patient's position offers advantages. When venous return is too great, this "extra volume" can easily be removed from the circulation by placing the patient in reverse trendlenberg position. This maneuver is especially helpful during the time when proximal anastomoses are being done and systemic blood pressure should be somewhat decreased.

Myocardial depression is generally due to myocardial ischemia. The use of new flow restors to provide blood shunting during the anastomosis effectively decreases ischemia and improves myocardial function [23, 24]. Topical hypothermia can be of concern and surgeons should irrigate the heart with warm solutions [25]. This usually reverses myocardial depression instantly. However sometimes is necessary to release the traction of the heart and return it to normal anatomic position to improve the myocardial function to normal. Once again, effective communication between all members of the operating team is important to assure that adequate measures are taken to restore adequate cardiac function.

Hypotensive episodes in the presence of adequate cardiac output and mixed venous oxygen saturation are indicative of low systemic vascular resistance. Administration of an alpha adrenergic agonist generally improves low blood pressure state and increase venous return temporarily. TEE and pulmonary wedge pressures are used to estimate the fluid requirement during TROPCAB procedure 14, 16, 20. The choice of crystalloid versus colloid is still controversial [26, 27, 28, 29, 30]. The general consensus is to use a combination of colloid and crystalloid if the alveolar membrane is intact. If there is a leaky membrane, use of colloid is strongly discouraged [31, 32]. The cost of colloids should also be justified when decision is being made for the type fluid replacement.

Adequate cardiac output monitored continuously throughout surgery assures the anesthesiologist that there is satisfactory perfusion to brain and other vital organs. It is important to note that acceptable blood pressures always does not translate into adequate tissue perfusion. Proper measure to restore cardiac output and tissue perfusion is usually attained by improving the venous return and increasing myocardial contractility. As the last resource temporary administration of alpha agonists such as phenylephrine may be advantageous if the perfusion pressures are low because of dilated vasculature. Use of D1- dopaminergic agonist such as fenoldopam may be beneficial in protecting renal perfusion in-patient with marginal kidney function with the adverse tachycardia effects of dopamine [33, 34, 35]. In some centers the adequacy of cerebral perfusion and the depth of anesthesia are continuously monitored by bispectal analysis technology [36, 37, 38, 39]. This tool of monitoring has been proven to be helpful and a sensitive measure of the cerebral activity.

FAST TRACKING

Early extubation and decreasing duration of mechanical ventilatory support has been recently advocate by many centers [40, 41, 42, 43]. Several studies have show that there is no difference in cardiac complication and stress on the newly revascularized heart between a group of patients that received traditional so called stress-free, high-dose narcotic based anesthesia and the patients who underwent a fast-tracking protocol [44, 45, 46]. With fast-tracking, the goal is to extubate patients within 3-6 hours after surgery [47, 48]. By doing this, the patient discomfort being intubated will be decreased as will the cost involved in patient care 41. The success of early extubation depends on an adequate perioperative pain control with a technique that results in less respiratory depression postoperatively [49, 50].

The continuous presence of anesthesiologist at the scene and his/her involvement during immediate postoperative care is the key factor in attaining the goal of fast-tracking in cardiac surgery. Availability of anesthesiologist will enable the cardiac care team to provide and adequate pain control, respiratory care, ventilatory management, as well as management of any hemodynamic instability. Immediate postoperative care in reality is the continuation of intraoperative care and familiarity of the anesthesiologist to the patients and their particular need is a real plus in taking care of these critically ill patients.

Early extubation and fast-tracking demand the use of low dose narcotic anesthesia techniques, which may not sufficiently anesthetize the patient to blunt the sympathetic response. The use of ultrashort-acting narcotics such as remifentanyl is advocated to quickly increase the depth of anesthesia and analgesia without prolonging the recovery of patients from anesthesia [51]. Addition of a short-acting beta blocking agent such as esmolol 0.5 mg/kg at the time of intubation and skin incision is also a useful measure to decrease the tachycardic response and decrease myocardial oxygen demand during TROPCAB procedures [52, 53, 54, 55, 56, 57].

Induction of anesthesia in patients undergoing TROPCAB procedures has to be tailored for a fast recovery while at the same time providing adequate levels of anesthesia to block the tachycardic-hypertensive response during laryngoscopy and endotracheal intubation. A fast-acting hypnotic agent (e.g., propofol, and etomidate) is generally used in conjunction with moderate amount of narcotics (fentanyl or sufentanil). Choice of the induction agent depends on preoperative myocardial function. In patients with depressed ventricular function, etomidate is generally preferred over propofol to avoid hypotension and maintain cardiovascular stability [58]. If neuroaxial analgesia techniques have been used prior to induction the dose of systemic narcotic should be decreased accordingly. In these cases slight elevation of the head of the patients will decrease the chance of pulmonary aspiration. Rapid sequence induction is strongly discouraged unless there is a high suspicion of gastric regurgitation and the possibility of aspiration. Even in highly controlled situations, rapid sequence induction results increased myocardial oxygen demand and ischemia often despite the use of rapid acting narcotics such as remifentanyl 51.

A non-depolarizing neuromuscular blocking (NMB) agent is generally administered as part of the anesthetic with duration of action and hemodynamic effects the prime considerations determining choice. Pancuronium, a long acting agent, is often given in full dose at induction. Large doses of pancurionium can cause tachcardia, but are generally metabolized by the end of the surgical procedure 59, [60]. A shorter-acting NMB agent, that is more hemodynamically stable such as rocuronium or cis-atracurium can be used throughout the case or as an additional agent followed by small doses of pancuronium if additional muscle relaxation is needed. Interaction between some of the short-acting NMB agents (e.g., atracurium and mivacuronium) and pancuronium should be kept in mind that may result in prolonged muscle weakness [61, 62, 63]. Essentially almost all the agents can safely be used during TROPCAB if the level of neuromuscular blockade is continuously monitored. Preoperative kidney function is an important in deciding which NMB agent should be utilized. If the preoperative levels of creatinine are relatively high, it is reasonable to avoid pancuronium since this drug is mainly eliminated via kidneys. Cis-atracurium appears to be an attractive alternative in these patients62.

Oxygen is generally administered to patients intraoperatively in hope that it may increase oxygen both reserve and myocardial supply. Oxygen is not without its complications; molecular oxygen may generate reactive species and other inflammatory mediators during an ischemic-reperfusion injury [64]. This type inflammatory injury has a very high incidence during coronary revascularization procedures [65, 66]. Additional ventilatory changes may occur during harvesting of the internal mammary artery which requires meticulous dissection without damaging the vasovasarum. Decreasing tidal volume during the dissection increases the surgical exposure and may expedite the duration of harvesting. The respiratory rate needs to be increased to maintain adequate alveolar ventilation. If TROPCAB is done through a thoracotomy incision (MIDCAB) the use of double lumen tubes with one lung ventilation is advocated to provide a surgical exposure [67]. Univent tubes are alternative options for this purpose. Either may result in increased shunting of blood flow and decreased oxygenation 67.

POSTOPERATIVE ANALGESIA

Analgesia is an important part of balanced anesthesia techniques. Its importance is even increased in patients that are already suffering from a limited myocardial perfusion. Perioperative pain is associated with increases in total oxygen consumption and causes a quick increase in myocardial oxygen demand by induction of a tachycardia-hypertension response. Therefore, analgesia and pain management should play a major role in taking care of patients undergoing coronary revascularization procedures. Furthermore, adequate pain control enables patients to increase the depth of breathing and coughing that are important in respiratory physiology. Early extubation and weaning from ventilation are not possible without adequate analgesia and pain control. In a novel approach, the addition of intrathecal opioids (mixture of fentanyl 1μg/kg and preservative free morphine 7μg/kg) prior to induction of anesthesia increases the quality of pain control during intraoperative and early postoperative period [68]. Using this technique, almost 75% of patients can be extubated in the operating theater 68. Intrathecal opioids provide a smoother transition between intraoperative and postoperative periods and decrease pain-related postoperative complications.

Patient-controlled analgesia (PCA) is an excellent addition to the post operative pain management regimen in these patients. When using PCA pumps in addition to intrathecal analgesia, the loading dose and a continuous infusion of narcotics should be omitted to avoid possible delayed respiratory depression. Thoracic epidural administration of narcotics mixed with dilute concentrations of local anesthetics has also been used safely for pain management in patients undergoing MIDCAB. Despite several studies in the literature regarding their safety, of foremost concern with these techniques is the risk of epidural hematoma associated with full heparinization.

BLOOD PRODUCTS UTILIZATION

With the decrease in blood product utilization offered by off-pump bypass techniques, there may be a concurrent decrease in the risk of transmitting blood-borne pathogens, blood transfusion reactions and the associated risk of non-autologous transfusion. There is a decrease in bleeding with “off-pump” when compared to CPB [69]. This may be a result of the partial heparinization technique employed in off-pump revascularization when compared to the “full” heparinization used in conventional CPB since there is less derangement of the clotting cascade. In addition, the damage caused to both clotting factors and platelets by CPB is eliminated.

CONCLUSIONS

TROPCAB has the potential to revolutionize cardiac surgery. The operative team needs to communicate well to realize that potential. Studies have shown that there is less of a need for blood products and no additional operating room time or intensive care unit stay are incurred. Once the technical aspects of TROCAB have been mastered both by surgeons and anesthesiologists, there exists the potential to decrease both intensive care unit and overall hospital length of stay.

Therefore, hemodynamic dysfunction and coagulopathy are not the only potential benefits of off-pump technique. If studies show that there are also less neurologic sequelae, less intraoperative myocardial damage and less renal damage, the number of off-pump cases may continue to rise. Decreasing post-operative complications is the next logical step to improving cardiac surgery outcomes. TROCAB has the potential to do just that.

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