Cardiac Anesthesia for the Occasional Cardiac Anesthesiologist
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Stem Case and Key Questions Content
A 55 year old male with history of hypertension and diabetes mellitus type 2 presents for elective three-vessel coronary artery bypass grafting 5 days after a non-ST elevation myocardial infarction. A 55 year old male presents for a three-vessel coronary artery bypass grafting surgery 5 days after a NSTEMI. He is 178 cm tall and weighs 110 kg. Over the last two months he has developed dyspnea on exertion and eventually went to the ER where his troponin levels were elevated. An EKG showed non-specific ST changes. Angiography revealed three-vessel coronary artery disease. He was then referred to the cardiothoracic surgery team. He has a history of hypertension and diabetes mellitus type 2 for which he takes amlodipine and metformin.

What additional information do you need?

Which laboratory studies/tests are essential for the preoperative evaluation of this patient?

Are blood type and antibody screening sufficient? Will you order blood products prior to surgery?

Which ones?

A transthoracic echocardiogram shows a left ventricular ejection fraction of 40 - 45% with no regional wall motion abnormalities. His finger stick blood glucose level on the morning of surgery is 335 mg/dL.

Would you delay or cancel the case because of the glucose? How would you treat?

The patient states that he took metformin yesterday. Is that a problem?

The preoperative issues have been resolved. The patient is now in the operating room with standard ASA monitors, an arterial line, single PIV, and preoxygenation.
How would you induce the patient? What is the “best” induction drug? Compare/contrast propofol vs. etomidate vs. midazolam/fentanyl induction.

Laryngoscopy and intubation are uneventful. You attempt to establish venous access in the right internal jugular vein.

Is ultrasound the necessary for central venous access? Can you defend yourself if you don’t use ultrasound and cause an arterial puncture or pneumothorax?

The cardiac surgeon states that the cardiac function is poor and suggests the patient need a pulmonary artery catheter.

Is there value in placement of a pulmonary arterial catheter in a cardiac surgical patient? Potential complications?

Should you monitor cardiac output using arterial pulse variation instead?

Should you use a BIS monitor for this procedure?

The cardiac surgeon requests that a transesophageal echocardiogram be performed to evaluate the cardiac function intraoperatively.

What value does transesophageal echocardiography add to coronary artery bypass grafting procedures? Is it necessary?

Should an anesthesiologist who is not certified in transesophageal echocardiography attempt to interpret an echocardiogram?

If you see a regional wall motion abnormality, what does that signify?

What is the best medication for maintenance of anesthesia for this patient?

The cardiac surgeon requests that heparin be given to the patient in preparation for initiation of cardiopulmonary bypass. 33,000 units of unfractionated heparin are given intravenously. 10 minutes later the ACT is noted to be 275 seconds.

Is this value sufficient to proceed with cardiopulmonary bypass?
Should you consider an antifibrinolytic for this procedure?

The patient is placed on cardiopulmonary bypass. After approximately 60 minutes, the surgeon is on his last graft and requests that the patient be rewarmed.

What is your routine for separation from cardiopulmonary bypass?

Is there a recognized checklist of steps that should be performed prior to separation from cardiopulmonary bypass?

The hematocrit is 23%, do you transfuse on CPB or do you wait until you are separated from CPB and then transfuse?

The potassium level is 6.5meq/L, should you treat? How?

Separation from cardiopulmonary bypass is attempted, but is reinitiated after profound hypotension. How do you diagnose and treat the source of hypotension?

What would you suggest if the patient couldn’t be separated from cardiopulmonary bypass?

How does an IABP work? Describe the consequences of inappropriately timed balloon inflation.

The patient is separated from cardiopulmonary bypass. As the surgeon is inspecting the heart prior to closing the chest, he notices unclotted blood pooling beneath the heart and requests that you administer fresh frozen plasma. Is this a good idea?

What is the role of thromboelastography in cardiac surgery? What if it wasn’t available?

The patient continues to bleed presumably from the back of the heart. The surgeon continues to lift the heart and hemodynamic compromise occurs each time.

At what point should you recommend to the surgeon that you go back on bypass?

What are the consequences of going back on CPB?
What are the risks of massive transfusion?

What are the indications for use of recombinant factor VIIa?

After the bleeding has been controlled and you have successfully separated from CPB you notice that you are having difficulty pacing the heart after temporary epicardial pacing wires are placed.

What would you try first to ensure optimal function?

What mode should you pace the patient in?

After chest closure, you notice a new regional wall motion abnormality on TEE, but the patient remains hemodynamically stable.

What could this signify?

How would you manage? At what point would you recommend surgical re-exploration?

At the conclusion of the case, the cardiac surgeon requests that you extubate the patient on the operating room table.

Is this a good idea?

What if this procedure had been done without cardiopulmonary bypass? Would that make a difference?

**Model Discussion Content**

Cardiac surgery is a high risk event that typically involves patients with multiple comorbidities. The American Society of Anesthesiologists Task Force on Preanesthetic Evaluation suggests that such patients ideally should have a preanesthetic evaluation performed prior to the day of surgery.1 One study showed that elderly patients with severe coronary artery disease presenting for elective coronary artery bypass grafting were more likely to have an intraoperative or postoperative myocardial infarction if there was evidence of preoperative ischemia on ECG.2 Another study demonstrated that patients with an ejection fraction of 40% or greater had a 2.3% operative mortality rate for coronary bypass procedures compared to 4.8% for those with an ejection fraction between 20-40%.3 Chest x-rays are notorious for having a low incidence of discovering unpredictable findings4, although cardiac patients already have known pathology. One study showed increased complications in patients undergoing non-cardiac surgery who required preoperative treatment with insulin or had a...
preoperative serum creatinine greater than 2.0 mg/dL. Due to the possibility of significant blood loss, a CBC along with a type and cross are reasonable laboratory studies.

The American Diabetic Association guidelines for perioperative diabetes management recommend that critically ill hospitalized patients with known diabetes undergo glucose monitoring and treatment with insulin infusion to maintain a fasting random glucose level no greater than 180mg/dl, and that once insulin therapy is started to maintain a glucose range of 140mg/dl - 180mg/dl. The timing of metformin administration prior to elective surgery is controversial given the concern for postoperative lactic acidosis. However, it has been reported that this risk of lactic acidosis has not been proven in surgical patients and the improved serum glucose control seen with administration of metformin may have beneficial cardiovascular effects.

Induction of anesthesia for cardiac surgical patients varies depending on severity of illness, acuity of surgery, the type of procedure and on potential plans for an early extubation. Propofol is a commonly used intravenous induction agent used in cardiac surgery; causing a reduction in both preload and afterload with little effect on myocardial contractility. Etomidate has been shown to have less pronounced hemodynamic consequences when compared to propofol when used for induction of anesthesia. However, a single bolus of etomidate inhibits the hypothalamic-pituitary-adrenal axis response for more than 24 h in patients undergoing elective cardiac surgery, but no increase in vasopressor requirements. Etomidate is commonly used in cardiac patients with impaired ventricular function, but its use in patients with normal cardiac function is controversial given its decreased ability to blunt the autonomic response to laryngoscopy; this can result in hypertension and tachycardia, especially with the use of a low-narcotic based induction strategy. Benzodiazepines, when used in combination with fentanyl, can cause a 20% reduction in cardiac output when compared to opioids alone. However, the safety of this combination of induction drugs has been widely studied and most investigators have found it to be both safe and effective.

Maintenance of anesthesia is typically accomplished using a balanced anesthetic technique with the goal of early post-operative extubation in the ICU within 2-6 hours. Both laboratory and clinical evidence continues to mount supporting the use of volatile anesthetics in the care of patients undergoing coronary artery bypass grafting (CABG) surgery. The pharmacologic preconditioning caused by activation of a protective cellular response while using volatile anesthetics has been shown to reduce myocardial infarction size after periods of ischemia and protect the heart against post ischemic LV dysfunction. In practice, no one approach to anesthetic management for CABG procedures is best for all patients. Most combinations of hypnotic induction agents, opioids, and volatile anesthetic agents have been used with good results in the hands of experienced physicians particularly with doses titrated to effect.

The placement of central venous catheters is a routine aspect of the anesthetic care for the cardiac
surgical patient. However, as the availability and ease of use of newer portable ultrasound equipment continues to be enhanced, controversy over whether or not its use should be considered the standard of care during catheter placement has arisen. Use of ultrasound guidance is now recommended by the American Society of Anesthesiologists (ASA) guidelines for central catheter insertion for either the internal jugular or femoral sites but equivocal for the subclavian site when used in non-emergent situations. The pulmonary artery catheter was once widely accepted as a routine monitor for almost all cardiac surgical procedures and has received extensive study in the literature. However, pulmonary artery catheterization has fallen out of favor in recent years with increased utilization of transesophageal echocardiography (TEE) and more wide spread acceptance of intra-arterial cardiac output (CO) monitoring. The recognition of increased number of complications from inappropriate management based upon pulmonary artery catheter information has led some to abandon its use in centers that do not routinely employ it as a monitor. The 2013 ASA practice guidelines for pulmonary artery (PA) catheter insertion state that the decision to place a PA catheter is one based upon three factors: the patient, the procedure, and the local practice setting. The guidelines do not list specific procedures as being either appropriate or inappropriate for PA catheter placement but allow flexibility for the physician to determine appropriateness based on the patients hemodynamic status and expected derangements in cases either deemed to be low, moderate and high risk for large fluid shifts potentially causing end-organ damage.

The routine use of TEE is now recommended for all cardiac or thoracic aortic surgery, which includes most patients undergoing CABG or off-pump coronary artery bypass graft surgery. TEE can provide valuable information about volume status, regional wall motion abnormalities, new onset mitral regurgitation and allow one to judge the response to anesthetic interventions. Regional wall motion abnormalities (RWMA) can signify new areas of ischemia, although these changes are sensitive but not very specific and can be seen with changes in preload, afterload, or with pacing after separation from cardiopulmonary bypass. The transgastric mid papillary short axis view is commonly used to assess for RWMA because this image captures the territories of the three main coronary arteries; the caveat being that this view will still miss wall motion abnormalities of the basal and apical segments. A comprehensive TEE examination is recommended by the American Society of Echocardiography/Society of Cardiovascular Anesthesiologists Task Force before and after cardiopulmonary bypass (CPB).

Heparin is a vital component to successful cardiac surgery that allows implementation of cardiopulmonary bypass and reduces the risk of thrombotic and bleeding complications related to blood exposure to the CPB circuit. The individual anticoagulant response to heparin varies tremendously. A typical dose of unfractionated heparin for CPB is 200 to 400 U/kg. Up to 22% of patients do not adequately respond to heparin and are termed heparin resistant. Several observations suggest that decreased levels of antithrombin III (AT III) mediate heparin resistance; these observations lack sufficient evidence to establish this relationship. Other potential causes of
heparin resistance include hemodilution, previous heparin therapy, infection, consumptive coagulopathy, congenital antithrombin deficiency, etc. Additional heparin administration is the most common effective treatment to reach a goal activated clotting time (ACT) of 400 - 480 seconds. Amounts up to 800U/kg may be necessary to achieve an adequate ACT. If additional heparin is ineffective, other alternatives include transfusion of fresh frozen plasma (FFP) or administration of AT III concentrates. The decision to administer FFP instead of AT III concentrates in suspected AT III deficiency should be carefully weighed not only for the infection risks associated with transfusion of blood products but also because of the increased risk of transfusion-related acute lung injury. A report by Metz and Keats did not document any adverse effects of thrombosis or excessive bleeding in 51 patients undergoing CPB whose ACT was less than 400 seconds.

Prophylactic antifibrinolytic therapy has been documented to decrease blood loss as well as amount of blood transfused in a general population of cardiac surgery patients. Cardiac surgery patients undergoing repeat operations may benefit particularly from prophylactic antifibrinolytic administration.

Separation from cardiopulmonary bypass is a complex process that requires reversal of the processes and techniques used to initiate and maintain CPB. These including reversal of hypothermia, reinstitution of a native or paced cardiac rhythm, restoration of systemic arterial blood pressure, correction of any deranged metabolic parameters, restoration of ventilation, preparation and initiation of inotropes/vasopressors, preparation of any additional blood products that are anticipated to be needed after separation from cardiopulmonary bypass, insuring the patient is adequately anesthetized and muscle paralysis remains adequate. Neurologic monitors such as the bispectral index can be used to help judge the depth of anesthesia during and after weaning from CPB. Rewarming is a gradual process that must be undertaken in a controlled fashion as to avoid denaturation of plasma proteins, possible cerebral hyperthermia and prevention of bubble formation from dissolved. Rewarming is considered complete when the nasopharyngeal temperature is 36 - 37°C and the rectal/bladder temperature is greater than or equal to 35°C; it is not recommended reaching a temperature greater than 37°C. Before separation from CPB, the heart must have either a stable organized rhythm or a paced rhythm. Metabolic derangements are common at the end of cardiopulmonary bypass and can include perturbations of the pH, pO2, pCO2, hemoglobin or hematocrit, potassium, glucose and ionized calcium. Hypokalemia can be treated with administration of increments of 5 - 10mEq KCL intravenously over one to two minutes while on CPB and subsequently rechecked prior to separation. Hyperkalemia with values exceeding 6 mEq/L is not uncommon can be caused by systemic uptake of potassium containing cardioplegia or from other causes such as hemolysis, tissue necrosis or acidemia. Treatment is directed at reducing the potassium level to an institutionally specific normal value by standard measures which include diuresis, calcium administration, insulin and glucose therapy or alkali therapy. A hematocrit of at least 20% to 25% is sought before discontinuation of
cardiopulmonary bypass. A study involving healthy dogs demonstrated that a hematocrit below 17-20% could no longer support the systemic oxygen needs. Prior to separation from CPB, all monitors and access catheters should be checked, zeroed and calibrated for accuracy. Checklists have been shown to reduce critical task omission prior to separation from CPB for trainees and could be a helpful tool for practicing anesthesiologists as well.

Hypotension upon separation of cardiopulmonary bypass is a relatively common problem that must be rapidly evaluated and treated. A focused assessment of the patient’s heart rate, rhythm, contractility, preload and afterload often reveals the inciting cause of hypotension which can then be direct treatment. In the setting of post-bypass hypotension thought to be related to heart failure, immediate re-evaluation of bypass graft integrity with a flow probe can be helpful. Optimization of pharmacological therapy with a combination of inotropes and vaspressors can be of significant benefit. However, there are cases of hypotension which appear refractory to traditional treatments despite optimization of the prior hemodynamic variables and escalation of inotropes/vasopressors. The vasoplegic syndrome is described as hypotension associated with profound vasodilation unresponsive to conventional catecholamines. Traditional treatment for this vasoplegic syndrome has centered on administration of two drugs: arginine vasopressin and methylene blue. Vasopressin’s vasopressor effect is mediated through the VP1 receptor which is different than the vasopressor effects of catecholamines, and it can be infused to treat hypotension that occurs after cardiac surgery. Methylene blue works by inhibiting guanylate cyclase and the resultant production of cyclic guanosine monophosphate, a substance known to increase vascular smooth muscle relaxation. Though controversial, methylene blue has been used as a rescue agent for refractory hypotension in cardiac surgery and its use has been reported to have no serious side effects, though its use is contraindicated in patients taking selective serotonin reuptake inhibitors for depression. After complete exhaustion of pharmacological options, mechanical support of ventricular function is considered. The intra-aortic balloon pump is designed to augment flow to the coronary arteries during diastole and unload the left ventricle during systole. The balloon is positioned in the descending aorta just distal to the left subclavian takeoff. Counterpulsation displaces blood in the descending aorta in a manner that is synchronized with the cardiac cycles which often results in improved cardiac output, coronary blood flow, and mean arterial pressure. Balloon inflation should be timed to occur at the time of aortic valve closure or LV strain and aortic insufficiency can result. Inflation too late can result in decreased coronary artery perfusion pressure. Other mechanical support devices include left and right ventricular assist devices and varying types of extracorporeal membrane oxygenation.

The approach to the bleeding cardiac surgical patient is unique in that one must begin the process of quickly diagnosing the cause of bleeding while simultaneously treating the presumed cause of bleeding. Surgical causes of bleeding should be sought out and corrected immediately. Inadequate reversal of heparin must be ruled out. Impaired coagulation caused by prolonged cardiopulmonary bypass time, hypothermia, thrombocytopenia, hemodilution, and increased consumption of clotting
factors are all potential causes of bleeding after cardiac surgery. Guidelines for the management of bleeding after cardiopulmonary bypass for routine CABG surgery are published by the Society of Thoracic Surgeons and Society of Cardiovascular Anesthesiologists, and provide a step-wise approach to the bleeding surgical patient. Banked blood should be infused to maintain a hemoglobin concentration that allows appropriate oxygen delivery to tissues. Although routine prophylactic administration of FFP or platelets plays no role in modern cardiac surgical care, demonstration of a platelet count less than 100,000/mm³ or prolongation of the PT or PTT despite adequate heparin neutralization in a patient actively bleeding is an indication for platelet or plasma replacement. Each unit of platelet concentrate will increase the platelet count by about 20,000/mm³ in the adult. During cardiac surgery, shed blood in the mediastinum can be returned to the patient after filtration. However, this cell saver blood contains only RBC without any additional clotting factors or platelets and can contribute to ongoing bleeding by its dilution effect on coagulation factors. Massive transfusion during or after cardiac surgery has recently trended towards an increased utilization of 1:1 or similar ratios of FFP: RBC’s. Reduced utilization of RBC’s and improved survival have been noted in the trauma literature using this ratio. The exact ratio of FFP, RBC’s and platelets that provides best hemostasis in the case of massive hemorrhage during cardiac surgery has not been established and the cause of bleeding must be sought out and treated specifically in each patient. Thromboelastography (TEG) is a useful tool for diagnosing and directing treatment of perioperative coagulopathy in patients undergoing cardiac surgical procedures due to a variety of potential coagulation defects that may exist. TEG can deliver information regarding platelet function, fibrinogen function, fibrinolysis, and the integrity of the coagulation system in as little as 15 - 30 minutes. For massive hemorrhage that proves refractory to traditional therapy, some advocate the off label use of recombinant factor VIIa; there are some anecdotal reports in which a marked decrease in bleeding takes place after its use, though this is controversial due to the concern for graft thrombosis. Recombinant factor VIIa is approved for use in patients with hemophilia A or B who are resistant to factor VIII concentrates. Its use is usually reserved for cases of severe hemorrhage in which other options have often been exhausted. Bypass-induced coagulopathy represents one of the most prevalent pathophysiologic events associated with the exposure of blood to foreign surfaces. Exposure of blood to the components of the CPB circuit evokes contact activation of platelets, granulocytes, and proteins associated with the intrinsic pathway. The hemodilutional effect of instituting CPB can be magnified if the patient has just recently been separated from CPB and has not yet returned to their baseline level of hemostasis prior to reinstitution of CPB. This situation can lead to the increased need for transfusion of clotting factors and platelets.

Dysrhythmias are a common cause of hemodynamic perturbations after cardiac surgery. Temporary epicardial pacemaker placement is commonly used for the treatment of symptomatic bradyarrhythmia, cardiac arrest, and can be placed prophylactically. Temporary antitachycardiac pacing is also commonly used after cardiac surgery. Atrioventricular junctional tachycardia after CPB can be managed by atrial or atrioventricular sequential overdrive pacing attempting to wean as quickly as
possible from A-V pacing to atrial pacing to improve stroke volume and reduce mitral regurgitation. Paroxysmal supraventricular tachycardia and Type I atrial flutter can also be managed with epicardial pacing; initially by overdrive pacing for 20-30 seconds and then decreasing the rate slowly after 1:1 beat capture has been established. The 2011 American College of Cardiology Foundation/American Heart Association guidelines for coronary artery bypass graft surgery recommend administration of prophylactic beta blockers for at least 24 hours before CABG surgery and that they should be restarted after surgery as soon as possible for all patients without contraindication, in order to reduce the incidence or clinical sequelae of postoperative atrial.49 For patients with contraindications to beta blockade and considered high risk for postoperative atrial fibrillation, preoperative amiodarone is recommended.50

Increasingly greater focus is being placed on limiting resource utilization in today’s healthcare environment and the cardiac surgery arena is certainly no exception. Fast-track management of cardiac surgical patients with same day admission, early extubation and ambulation, and early ICU and hospital discharge with early follow-up is being advocated as a potential cost saving measure.51 Suggested criteria for early extubation include adequate surgical hemostasis, normothermia with a body temperature between 36oC - 38oC, stable hemodynamics on minimal inotropes with a cardiac index >2.0 L/min/m2 with a stable cardiac rhythm, adequate urine output with stable electrolytes, adequate motor strength, spontaneous ventilation at a normal respiratory rate with adequate arterial blood gases and a patient that is awake, alert, and cooperative. Early extubation (less than 10 hours after cardiac surgery) has been shown to have no significant differences in major morbidity or mortality and may reduce ICU length of stay and overall hospital length of stay in selected patients.51, 52

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