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Routine Postoperative Care of Patients Undergoing Coronary Artery Bypass Grafting on Cardiopulmonary Bypass

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Abstract

The postoperative course of a patient undergoing cardiac surgery (CS) is dictated by a largely predictable set of interactions between disease-specific and therapeutic factors. ICU personnel need to quickly develop a detailed understanding of the patient's current status and how critical care resources can be used to promote further recovery and eventual independence from external support. The goal of this article is to describe a typical operative and postoperative course, with emphasis on the latter, and the diagnostic and therapeutic options necessary for the proper care of these patients. This paper will focus on coronary artery bypass grafting as a model for understanding the course of CS patients; however, many of the principles discussed are applicable to most cardiac surgery patients.

Keywords

cardiac surgery, intensive care, cardiopulmonary bypass, resuscitation

Introduction

The postoperative course of a patient undergoing cardiac surgery (CS) is dictated by a largely predictable set of interactions between disease-specific and therapeutic factors. Components of this mixture include the impacts of surgical stress in general, specifics of the patient's operative course including use of cardiopulmonary bypass, aortic cross-clamping, and the presence of other comorbidities including age. In general terms, the intensive care staff will be assuming the care of a patient whose heart was completely arrested 2 hours previously, and that has attained—either spontaneously or with artificial support—a level of function believed to meet the body's current needs. Intensive care unit (ICU) personnel need to quickly develop a detailed understanding of the patient's current status and how critical care resources can be used to promote further recovery and eventual independence from external support. While this can be a daunting task for the uninitiated, experience will lead one recognize a number of recurring themes in the postoperative care of CS patients. For the astute provider, the care of the CS patient eventually becomes recognizing which patients are conforming to a typical postoperative course and which patients require additional thought and attention. The goal of this article is to describe a typical operative and postoperative course, with emphasis on the latter, and the diagnostic and therapeutic options necessary for the proper care of these patients. This article will focus on coronary artery bypass grafting (CABG) as a model for understanding the course of CS patients; however, many of the principles discussed are applicable to most CS patients. Other articles in this series address concerns specific to other procedures, and the reader is encouraged to consult these works as well.

Preoperative Concerns

The presence of coronary artery disease is typically driven by risk factors such as diabetes mellitus, hypertension, smoking history,[1] and in some cases long-standing neglect of health. Other comorbidities including lung and kidney diseases, oncologic diagnoses, and endocrine disturbances are often present to varying degrees. The intensivist should have a management plan for all significant medical issues, including identification of both parenteral and enteral options for key medications. The intensivist should strive to understand the patient's preoperative level of function and cardiac symptoms. Postoperative management of pain, fluid status, and heart rhythm can often oppose proper management of renal and pulmonary conditions and requires a cautious approach that anticipates complications.

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Table 1. Elements of Cardiopulmonary Bypass and Impact on Postoperative Care.

Requirement for Extracorporeal Circulation	Impact on Postoperative Care
Full anticoagulation	Rebound heparinization; preempts regional anesthesia
Lungs collapsed, no ventilation (still operative field)	Decreased surfactant production, postoperative atelectasis, retrocardiac opacity, increased arterial–alveolar gradient, increased mucus plugging
Aortic cross-clamping (excludes heart from circulation)	Potential emboli to cerebral circulation; ischemic time to myocardium
Lower blood pressure	Potential compromise to cerebral circulation
Controlled hypothermia (to decrease myocardial and systemic oxygen demand)	Incomplete warming, shivering (increased VO_2), coagulopathy, vasodilation with postoperative warming, washout of renal medullary concentration gradient
Use of antifibrinolytics (reduces blood loss)	Increased risk for renal dysfunction with aprotinin
Pump prime (crystalloid, mannitol, albumin)	Hemodilution, diffuse loss of red cells, postoperative diuresis
Nonpulsatile circulation	Unknown
Extracorporeal circuit	Activation of platelets, depletion of granules

Intraoperative Concerns and the Conduct of Bypass Surgery

In addition to the generalized inflammation and oxidative burst that follows major operations, CS patients are exposed to a unique set of insults related to exposure extracorporeal circulation and aortic cross-clamping.[2] Table 1 lists these factors as well as their implications for postoperative recovery; as is discussed in another article in this series, off-pump CABG has the theoretical advantage of obviating the majority of these constraints.

In CABG surgery, the heart is accessed via median sternotomy. The pericardium is excised and large-bore cannulae are inserted into the aortic arch and right atrium to form the arterial and venous limbs of the cardiopulmonary bypass circuit. Smaller catheters are inserted into the ascending aorta and coronary sinus, allowing for administration of cardioplegic solution and for "venting" of blood returned via the bronchial circulation. Systemic anticoagulation is established and verified prior to commencement of cardiopulmonary bypass (CPB). Once on bypass, the heart is emptied, mechanical ventilation discontinued, and the heart is arrested with a high potassium cardioplegic solution. An aortic cross-clamp is placed proximal to the arterial (inflow) cannula to effectively exclude the heart from the artificial circulation. The heart is cooled with iced saline. With the heart still, coronary artery bypass "targets" are identified downstream of stenotic regions as indicated by prior angiography. Distal anastomoses of vein grafts or mammary artery conduits are established at the target sites. Adequate lengths of saphenous veins are excised from the legs, and internal mammary arteries are dissected free from the chest prior to bypass. Proximal anastomoses are finally established at appropriate sites of the ascending aorta. The cross-clamp is then removed and flow through the grafted arteries and veins is verified. In the following 10 to 15 minutes, ventilation is resumed, and the body is rewarmed. The requirements for pacing, inotropes, blood products, and vasoconstrictors are continually assessed during this period. Finally, the body is separated from bypass. Anticoagulation is reversed with protamine, and additional blood products and hemostatic agents are administered if needed. Heart function is constantly observed by the surgeons and anesthesiologists, both in the operative field and with the assistance of transesophageal echo (TEE) throughout the wean from bypass. The transition between artificial and native circulation reveals the quality of intrinsic cardiac function and its dependence on chronotrypy, inotropy, and pacing in order to maintain oxygen delivery. Difficulty with weaning from CPB is often the first sign of a difficult or prolonged postoperative course.[3] Finally, the chest is closed and the patient is made ready for transfer to the ICU.

Patient monitoring typically consists of some form of central access, an arterial line, and venous access sufficient for aggressive fluid and blood product resuscitation. The nature of central access and monitoring is highly institution-dependent and typically represents a cooperative arrangement between operative and ICU teams for perioperative care. Prior widespread use of pulmonary artery catheters in CS has given way to use of simple central venous catheters (CVC) and oximetric CVCs in less complicated patients. Arterial access may likewise range from simple catheters to those with analytic functions such as pulse contour analysis of stroke volume. TEE completes standard intraoperative monitoring. In addition to the aforementioned lines, CABG patients will typically have ventricular pacing wires, a mediastinal drain, a left chest tube if the internal mammary artery was excised, a urinary catheter, and bandages covering sternotomy and vein harvest sites.

Intraoperative analgesia and sedation is accomplished with high doses of synthetic opiates, benzodiazepines, and inhaled anesthetic agents. With fentanyl, very high initial loads provide stability during intubation through institution of cardiopulmonary bypass, and in some cases are sufficient for conduct of the entire operation. Judicious supplementation to this load often provides sufficient analgesia for an hour or more into the ICU; the self-tapering of this pharmacokinetic curve provides an opportunity for patient awakening and extubation. Perioperative factors such as poor lung function, ongoing resuscitation, unstable rhythms, and bleeding are best managed while not attempting concurrent extubation; sedative agents and doses should be selected in accordance with the patient's ability to be extubated within a few hours after the operation, and will thereby influence the immediate postoperative trajectory. Narcotics and sedatives are typically continued to promote stability until extubation is appropriate. Dexmedetomodine and propofol synergize with opiates and provide additional options for titratable sedatives and sparing of benzodiazepines. The former is associated with a reduced incidence of delirium in CS patients.[4] Greater use of titratable sedatives and opiates with lower accumulation and shorter duration are used in rapid extubation protocols. Bolus sedatives rather than infusions are generally recommended in critically ill patients and reduce accumulation and excessive dosing of these potentially harmful agents.[5,6] Neuromuscular monitoring for residual paralysis and readiness for reversal is crucial if early extubation is desired.

CABG patients typically have 3-vessel disease or left main equivalent disease. In studying the preoperative workup and communicating with the operative team, one should strive to understand the distribution of cardiac muscle into 3 general categories: territory that is functional with an adequate arterial supply, infarcted muscle, and functional muscle that is "at risk" due to a poor vascular supply. Understanding the proportions of these territories, their anatomic distribution, as well as measures of post-pump function will help guide expectations for ICU course and subsequent recovery. Occasionally, anatomic and technical constraints prevent full revascularization of "at risk" ventricular muscle; this territory should be an additional area of focus in postoperative care.

Postoperative Care

On arrival to the ICU, the patient should be transferred to the ICU monitoring system in an efficient and orderly manner.[7,8] Any formal sign over should not be attempted until physical transfer is complete, with perhaps the exception of orienting remarks such as "routine case" or "the blood pressure is down." Transfer should be team based and include ICU physicians and nurses and a cardiac surgeon and anesthesiologist. Key elements of the sign over particular to CS patients are listed in Table 2. Factors that typically differentiate patients from one another are narcotic requirements, oxygenation and ventilation problems, coagulopathy, the need for pacing or other ventricular support, and surgeon and anesthesiologist preferences regarding timing of extubation; these factors need to be highlighted during transfer of care. Intraoperative blood loss is diffuse with red cells lost to sponges, hardware, and the extracorporeal circuit and cell salvage equipment and all of its tubing. Immediate postoperative hematocrits in the mid-to-high 20s are quite common, even patients beginning in the low to mid-40s.

Table 2. General Outline of Sign Over Between Operative and ICU Team.

Surgeon	Anesthesiologist
Operation	Allergies
Degree of revascularization	Key medical problems
Cross-clamp and bypass times	Intubation difficulty
Difficulty weaning from bypass	Lines and quality
Pre- and post-pump function	Pre- and post-pump function
Drain location and drainage	Ease of weaning from bypass
Bleeding and coagulopathy	Drips and rationale for use
Family, social issues	Lung function, last ABG, A-a gradient
Plan for timely or later extubation	Urine output
	Glycemic control
	Antibiotics and dosing
	Antifibrinolytic
	Anesthetic drugs and doses
	Last paralytic
	Volume status, ideally relating CVP or PA measurements to echo findings

Abbreviations: ICU, intensive care unit; ABG, arterial blood gases; CVP, central venous pressure; PA, pulmonary artery.

Hemodynamics

The key determinants of organ perfusion are a blood pressure within the range that allows end organs to maintain constant blood flow and delivery of oxygen at values exceeding the current rate of consumption.[9] Ideally, the patient is resuscitated to these endpoints in the operating room. Mean pressures in the range of 65 to 90 and cardiac indices (CI) >2.5 L/min/m^2 are generally considered desirable and will permit successful extubation. Perhaps more than assuring the patient's vitals lie within the ideal range, the intensivist should strive to establish the individual character of each patient's hemodynamics. For example, one patient may easily attain a CI > 3.2 with minimal fluid therapy, and be able to maintain a mean arterial pressure (MAP) of 70 with no additional medications, while another may settle out at a lower index and require inotropes and vasopressors to maintain organ perfusion. Understanding the individual makeup will permit the intensive care team to detect perturbations to circulatory homeostasis and select proper therapy. The anesthesiologist can greatly assist the intensive care team by indicating the range of filling pressures that were associated with adequate ventricular filling on echo. In our experience, individualizing such data elements is far more important than striving to maintain "normal values" in postoperative care. From thoughtful inquiry into the patient's status, the intensivist should arrive at a sense of patient function and dependence on support. Assuming the patient is resuscitated, a "happy medium" can be defined in terms of:

An adequate blood pressure → derived from:
Adequate vascular tone (requiring vasopressors, or native tone?)
and
Adequate cardiac output or SvO2/ ScvO2 → derived from
Filling pressures believed to be euvolemic (CVP, PAD)
and
An adequate heart rate (native or paced??)
and
Adequate inotropic state (native or inotrope-assisted??)
→ Giving rise to a resuscitated state based on:
Normal acid-base status
Warm extremities
Adequate urine output
Other assessable organs functioning well

With a sense of the patient's happy medium, recognition of patterns of deviation can be used to diagnose and treat sources of change and instability. Blood pressure decreases are very common during the first day of postoperative care. Three very common sources of postoperative hypotension are described in Table 3. Hypovolemia is characterized by decreases in both filling pressures and cardiac output. Central venous pressure (CVP) or pulmonary artery diastolic pressure (PAD) will decrease in parallel to blood pressure. With hypovolemia, one should inspect chest tube and wounds for excessive blood loss. Clear hypervolemia is quite common in the early postoperative period and occurs with brisk diuresis, warming, and redistribution of fluids—all of which are common in the immediate postoperative period. If a new acidosis is present, suspicion for overt or occult hemorrhage should be entertained, and it would be prudent to inspect drains and to obtain a hematocrit. Intrathoracic hemorrhage can result from errant chest tube insertion or from the vessels and area surrounding the internal mammary artery. Post-CABG patients can require fluid administration of 2 to 3 liters in the early ICU period. A rise in filling pressures (PAD or CVP) along with a decrease in blood pressure invokes a wider differential diagnosis that includes acutely worsening pump function, bypass graft abnormality, or functional/anatomical problem such as systolic anterior motion of the mitral valve or septal hypertrophy. More common to our experience is a cardiopulmonary interaction in which an increase in chest wall tone from shivering, awakening, or patient-ventilator dysynchrony creates an elevation in intrathoracic pressures (producing elevation in measured pressures), while in effect creating severe reductions in venous return and hence cardiac output. Sedation is the typical cure for this problem if immediate or near-term extubation is not anticipated. In severe cases of elevated filling pressures and depressed blood pressure and CO, paralysis can be useful, first as a means of diagnosing and interrupting the cardiopulmonary interaction, and if not present, as a tool to facilitate an urgent TEE exam to rule out tamponade, myocardial ischemia, or outflow obstruction. A state of low vascular tone (systematic vascular resistance) can result from exposure to CPB and from CS in general.[10,11] In a fluid-resuscitated patient, a maintained or elevated cardiac output and a decline in blood pressure are found with low systematic vascular resistance while filling pressures are unchanged or low. Vasopressors such as phenylephrine or norepinephrine are used to maintain blood pressure in the latter state but are often not needed as sedatives are weaned and the patient's own sense of arousal is sufficient to maintain adequate blood pressure. Situations requiring high doses of vasopressors in the absence of a known cause (allergy, spinal cord injury, autonomic insufficiency) is suggestive of adrenal insufficiency and deserves consideration of cortisol replacement. The normal range of random cortisol levels for post CS patients is not known, so clinical judgment needs to prevail in such cases.

It is quite common to see patients pass through phases of hypovolemia and low vascular tone as part of a normal postoperative course. Blood drainage of 100 to 200 mL over the first few postoperative days is equally common and can be managed with crystalloid fluid replacement. Patients often tolerate hematocrits in the low 20s without showing signs of instability or the need for transfusion. Myocardial edema resulting from cardioplegia as well as reperfusion injury results in decreased ventricular compliance that can be detected for at least 3 hours following the provoking insult.[12] Higher filling pressures may be required to maintain ventricular preload until the edema resolves, and the need for low-dose inotropes may be indicated by a decrease in $ScvO_2$ saturation.

Mechanical Ventilation

Weaning from ventilation follows typical parameters such as adequate gas exchange, minimal work of breathing, and ability to clear secretions. Issues particular to CS patients surround the use of extracorporeal circulation, aortic cross-clamping, and the potential for hemodynamic instability and neurologic injury. Generally, patients undergoing

Table 3. Common Scenarios of Postoperative Hypotension.

MAP	Filling Pressures	Cardiac Output/$ScvO_2$	Problem	Timing	Typical Management
Lower	Lower	Lower	Hypovolemia: clear, hemorrhagic	Immediate postoperative	Evaluate for hemorrhage; give fluid
Lower	Little change	Same to increased	Vasoplegia	2-4 hours postoperative	Add NE, NEO, VP
Lower	Increased	Lower	Cardiopulmonary interaction, tamponade, ischemia, SAM, septal obstruction	Sudden awakening, following stimulation	Sedate, paralyze, TEE if unresolved with paralysis
Lower	Increased	Mild decrease	Heart stiffening	6 hours postoperative	

Abbreviations: MAP, mean arterial pressure; NE, norepinephrine; NEO, phenylephrine; VP, vasopressin; TEE, transesophageal echo.

active resuscitation consisting of several liters of blood products or crystalloid, and active titration of vasoactive drugs or electrical therapy should remain sedated and ventilated until the trajectory is improved. Clinical judgment is warranted in this area; however, delaying extubation of such patients avoids problems such as development of pulmonary edema and greater myocardial and physiologic stress at a time when it may not be easily tolerated.

Aortic cross clamping and open heart procedures carry risks of cerebral embolism of aortic or valvular plaques that does not exist for most other surgical operations.[6] A deliberate neurologic exam prior to extubation will help rule out any abnormality that may complicate unassisted respiration. Collapse of lungs during CPB alone and in concert with other lung problems such as chronic obstructive pulmonary disease predispose the patient to mucus plugging, atelectasis, and lobar collapse. It is prudent to rule out the latter set of problems, as they can be more efficiently managed and resolved with bronchoscopy, directed suctioning, and lung recruitment while still on the ventilator. Phrenic nerve damage due to cold or mechanical trauma of this extrapericardial structure is also possible; however, it should rarely preclude extubation.[13,14]

Intensive care physicians often employ measurements such as generation of negative inspiratory force (NIF), vital capacity, and rapid shallow breathing indices (RSBI) to evaluate candidates for extubation. These measurements are generally applicable to longer-term ICU patients who experience significant diaphragmatic and skeletal muscle atrophy during hospitalization and provide objective evidence of residual muscle strength, endurance, and respiratory system compliance. The latter concerns are generally not applicable to patients who are intubated for less than 24 hours and who literally walked into the hospital the previous day. In our experience, performance of deep suctioning, NIF maneuvers, and all but brief spontaneous breathing trials can increase myocardial and circulatory stress that is potentially harmful to postoperative heart patients, and without clear benefit. A calm and cooperative patient who can clear secretions and follow commands is the ideal extubation candidate. Occasionally, emergence from sedation is accompanied by increased sympathetic activity often fueled by sensation of the tracheal tube. In these cases, one needs to make a quick judgment as to what may best serve the patient: resumption of sedation, immediate removal of the breathing tube, or control of hemodynamic changes with rapidly titratable agents such as sodium nitroprusside and esmolol. Prior investigation of the relevant resuscitative, pulmonary, and neurologic issues will add to one's confidence in extubation where appropriate.

At the time of extubation, most postoperative cardiac patients are in a significant positive fluid balance. If hemodynamically stable and no adverse effects are anticipated, gentle diuresis is usually begun at this juncture.

Chest Tubes and Bleeding

A chest tube is placed in the anterior mediastinum prior to sternal closure. An additional drain from the left chest may be present if the mammary artery has been dissected. Drainage in the first hour following chest closure should be less than 100 mL and should continue to taper off. A bleed of greater than 250 to 300 mL in the first hour warrants re-exploration and concomitant concern over coagulopathy.[15] With ongoing bleeding, the target hemoglobin concentration depends on the severity and trajectory of bleeding, individual patient factors, and general surgeon/intensivist tolerance of anemia. Generally, hematocrits as low as 20% are tolerated by completely revascularized CABG patients. Adding to the current practice of limiting transfusion in the critically ill is growing evidence of poor outcomes associated with blood transfusion. In particular, infusion of red cells stored greater than 14 days in CS patients is associated with a higher infectious risk, longer duration of mechanical ventilation, renal failure, and in-hospital and 1-year mortality.[16]

With medical bleeding, infusion of platelets and plasma are typically added to red cells in approximate equal ratios to mitigate coagulopathy. Fluid warmers should be used in the setting of significant postoperative bleeding. Cryoprecipitate may be needed in the context of prolonged bleeding, hepatic insufficiency, or suspected fibrinolysis. Antifibrinolytics tranexamic acid or epsilon aminocaproic acid (Amicar) are given intraoperatively as an initial bolus and infusion throughout the case. A previously favored antifibrinolytic, Aprotinin, has been abandoned due to its association with renal dysfunction and mortality.[17,18] Additionally, back diffusion of heparin from peripheral tissues to the bloodstream can lead to an elevation in partial thromboplastin time and activated coagulation time known as "heparin rebound"[19,20]; a small supplemental dose of protamine (50 mg) is appropriate therapy for the latter.

In addition to frequent inspection of chest tube drainage in the early postoperative period, an unexplained drop in hematocrit should prompt inquiry into other potential sources of bleeding such as femoral catheterization sites, vein harvest sites, and intrathoracic bleeding (mammary harvest, line placement, etc). While necessary for management of persistent bleeding or mechanical obstruction to cardiac filling, taking the patient back to the operating room is associated with significant increases in deep sternal wound infections, mechanical ventilation, and increased lengths of stay and mortality.[21] In routine cases, by postoperative day 3 to 4, chest tube drainage is less than 50 to 100 mL per day, and serosanguinous in quality, and is ready for removal.

Arrhythmias

Postoperative arrhythmias range from sinus and junctional bradycardias to both supraventricular and ventricular tachydysrhythmias. Most are self-limited and return to preoperative rhythm in a few weeks or less. Atrial fibrillation (AF) and flutter are the most common, with a combined incidence of around 30% in CABG patients and 40% to 50% with valve replacement.[22,23] The peak incidence of AF is postoperative days 2 to 4.[24] AF is associated with longer hospital stays and increased perioperative morbidity and mortality including stroke, hemodynamic instability, and exposure to drug toxicities.[23-25] Underlying factors for AF are a source of speculation and include fluid shifts, electrolyte disturbances, perioperative inflammation, and various psychological stresses.[26] The incidence increases with age.[25] There is no evidence regarding the need for rate versus rhythm control of atrial fibrillation, so this decision is essentially made on a case-by-case basis that incudes weighing risks of prolonged anticoagulation.[23,27]

Ventricular arrhythmias can arise from ongoing myocardial ischemia, structurally or functionally abnormal cardiac tissue, and from contact with catheters. Pulmonary artery catheters can be inadvertently pulled back during transport, leaving their tips in the right ventricle, where this contact is a frequent source of PVCs and ventricular tachycardia.

Pericarditis

Constrictive pericarditis is a rare complication following CS, with a reported incidence of 0.2% to 0.3%.[28,29] Though it may occur after any cardiac surgical procedure, it is more common following CABG than valve surgery. More commonly, an acute pericarditis consisting of diffuse ST segment elevations throughout the precordial leads can be found in the early postoperative period.[30] The pattern of elevations crossing multiple coronary artery territories, unchanged cardiac output, and absence of regional wall motion abnormalities individually or collectively are pertinent negative findings for coronary thrombosis and help affirm the diagnosis. Therapy with nonsteroidal anti-inflammatory agents is initiated to attenuate inflammation and its progression.

Pain

Pain control is typically accomplished with a combination of opiates, acetaminophen, and nonsteroidal anti-inflammatory drugs, depending on the nature and degree of pain, and risk for renal injury (nonsteroidal anti-inflammatory drugs). The ability to breathe deeply, cough, and clear secretions is a rational end point for titration of pain medications. Needs to control pain from leg incisions and shoulder and positioning injuries rarely exceed the analgesic requirements for pulmonary toilet.

Infection Control

Prevention of sternal wound infections is an important concern in postoperative management. Comorbidities such as diabetes and peripheral vascular disease and diversion of the internal mammary artery each contribute to lower blood flow to the sternotomy and skin incision sites. Continuation of antibiotics for the first 24 hours of postoperative care has been associated with fewer surgical site infections.[31-33] Hyperglycemia is associated with increased risks for infections and mortality.[18] Tight control glucose in the range of 80 to 110 mg/dL glucose improved mortality in an influential single-center study[34]; however, the risks of hypoglycemia and related poor outcomes led to rethinking perioperative glucose targets.[35,36] The Society of Critical Care Medicine has recommended that blood glucose be maintained below 150 mg/dL, with an absolute ceiling of 180 mg/dL.[37] Insulin infusions may be initiated in the operating room, depending on local traditions and perceived needs for control; these are typically continued until the patient is receiving oral feedings, at which time a combination of standing and postprandial insulin is given. The most effective control is achieved in institutions that have protocols for testing and control.[38]

Central lines, urinary catheters, and other indwelling catheters should be assessed at least daily for their contribution to patient management and removed as soon as they are no longer needed. Other infection control strategies include adherence to hand hygiene,[33] proper care of central line hubs,[33] proper oral care,[39] positioning of ventilated patients,[40] and encouragement of lung expansion and deep breathing. Although use of incentive spirometery (IS) has not been shown to reduce the risk of postoperative pulmonary complications, studies to date are small and methodologically flawed[41]; however, IS remains a mainstay of postoperative pulmonary therapy in many ICUs.

Reduction of Risks to Other Organs

Much of postoperative care revolves around understanding the patient's comorbidities and prevention of secondary injuries. Operative mortality is inversely related to perioperative renal function in CABG patients, and can be as high as 9% in those requiring dialysis.[42] Mortality can reach close to 6% in patients not requiring dialysis, but who experience a greater than 30% decline in glomerular filtration rate (GFR); declines in GFR <30% have an 0.4% mortality.[43] Over-diuresis and injudicious use or timing of blood pressure and pain medicines and antibiotics can individually and collectively cause renal injury.[44]

Medical management of coronary artery disease should be concurrent with postoperative recovery. If taken previously, aspirin, beta-blockers, and statins are resumed once the patient is able to tolerate oral intake.[18,45] Prior blood pressure medications are typically started at low doses and in a staggered manner to prevent large swings in blood pressure. Diuretics are typically given to manage fluid status as a separate issue, but with the same concern for changes in blood pressure. Concurrent use of angiotensin-converting enzyme inhibitors and diuresis has the potential of providing insults to the kidney and should be avoided if there is any concern over renal reserve. Diabetes is certainly a large predisposing factor to renal injury causing one to exercise special caution with the aforementioned agents, antibiotics or any other intervention known to perturb renal function.[44]

Encouragement of coughing and deep breathing is essential to clearance of secretions and aeration of atelectatic lung, and prevention of pulmonary complications, which are common in in this population.[46] Patients with shallow respiration can maintain arterial blood gasses in the normal range. Thus, examination of patients should include inspection of incentive spirometery and the presence of pain or involuntary splinting when taking deep breaths. Bronchodilators should be added as indicated by clinical exam, even in the absence of a formal diagnosis of airflow obstruction.

A normal diet is often resumed on postoperative day 1. For patients with prolonged mechanical ventilation, trophic feeds should be started as soon as possible; full feeding can be deferred for up to a week, unless there is evidence of preoperative malnutrition.[47] Feeding can proceed even in patients with high vasopressor requirements.[48] There is no clinical advantage to early institution of parenteral nutrition in these or other critically ill populations.[49]

Conclusion

The management of postoperative CABG patients provides both challenging and rewarding experiences for the intensivist. Rarely does one encounter patients that can experience 2 to 3 prototypic forms of shock in an evening, and have a nice conversation with you the following day! Understanding the various patterns of instability and their underlying causes is necessary in understanding how to best manage preexisting and new medical conditions. Mastery of these concepts helps maintain a very low morbidity and mortality for these major operations.

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