Preface

Welcome to the first edition of Modern Concepts and Practices in Cardiothoracic Critical Care. Over the past two decades there has been a dramatic increase in patients requiring intensive care services. With cardiovascular disease ranking near the top as the etiology for admission to the intensive care unit (ICU) and the demographic trend of an aging population with multiple co-morbidities (primarily cardiac) a need for specialized cardiovascular critical care has been established. Furthermore, there will be a need for specific well-trained cardiovascular intensivists to meet the needs of this patient population. Educational resources designed to provide the latest information regarding cardiothoracic critical care are essential.

This book is intended for the medical students, residents, fellows, intensivists, anesthesiologists, cardiac surgeons, nurses, physician assistants and pharmacists who all care for patients following cardiothoracic surgery. We have tried to strike a balance between explaining the basic tenets of caring for these patients while also presenting the latest research and current controversies regarding the specialized management of these patients. We are especially grateful to the team of nationally and internationally renowned experts in cardiology, intensive care, cardiac anesthesiology, cardiac surgery, and pharmaceutical care that have each contributed chapters. This emphasizes the multidisciplinary nature of caring for patients in the cardiothoracic intensive care unit as well as their commitment and recognition of this increasingly specialized and unique field of critical care.

The book is divided into six sections. Section I involves an introduction to care of the cardiac surgical population. Here the epidemiology of the evolving cardiac surgical population is reviewed along with issues surrounding quality and safety, management of a cardiothoracic intensive care unit and training to work in this sub-specialized environment. Chapters on ethics and palliative care also round out this section helping to provide a framework for decision making in this vulnerable population. Section II focuses on the preoperative assessment and optimization of patients prior to undergoing cardiothoracic surgery. Chapters on acute coronary syndromes, valvular heart disease, and heart failure are emphasized. Section III reviews the basic pharmacology utilized in the cardiothoracic intensive care unit with an emphasis on inotropes & pressors, anticoagulation, sedation and analgesia, and vasodilating agents. Section IV involves a systems approach to cardiothoracic critical care. Over eight chapters a detailed approach of each of the current clinical areas of focus on daily rounds are reviewed. Section V emphasizes specific surgical techniques and postoperative concerns. Written specifically by surgeons, these eight chapters attempt to explain the most common procedures performed and the surgeon’s viewpoint on where the postoperative team should focus their efforts. Finally, Section VI discusses physiologic monitoring of the post-operative cardiac surgical patient. Current management of bleeding via point of care technology along with methods of invasive and non-invasive monitoring and the role of ultrasound and echocardiography are reviewed.
In chapter 1, Epidemiology, the authors highlight key historical events and describe an unprecedented trajectory and evolution in care practices that have helped shape modern cardiac surgery. They also make an appeal for additional research efforts which are needed to ensure sustained and innovative growth. While the timeline has been relatively abbreviated, there has been significant evolution in the field of cardiac surgery. These changes have been driven by a combination of operative innovation, changing patient demographics, and novel critical care resources, all of which have allowed today’s surgeons to treat a myriad of conditions among increasingly higher risk patient cohorts. At the same time, this has forced providers to expand their clinical skill sets, embrace multidisciplinary collaboration, enhance postoperative care, and intensify the rigor by which outcomes and quality are being measured. In spite of this increasing complexity, however, mortality in cardiac surgery continues to improve.

Quality improvement is a goal of all institutions but effective quality improvement programs have been difficult to create and sustain. Cardiac surgery has long been a pioneer in the quality improvement process through protocolization, large database analysis, and evidence based research. In Chapter 2, Quality and Safety, the authors discuss the theoretical foundation for quality improvement in medicine, and address current quality improvement strategies in the cardiothoracic ICU including care bundles, large database review, and externally promulgated quality programs such as the Surgical Care Improvement Project (SCIP) or the Physician Quality Reporting Initiative (PQRS). Controversies from national quality improvement programs including SCIP, extended staffing, and the value of quality culture will be discussed.

Education and training has been the cornerstone of medicine from the days of the Hippocratic oath. What began as an informal apprenticeship has become a standardized curriculum, with heavy influence from the education sciences, regulatory bodies and societal demands. As an area of rigorous study in its own right, Physicians have a responsibility to understand education theory and their effective application in clinical practice in order to fulfill their professional obligations. Chapter 3, Education and Training, will outline past and current education theory relevant to critical care practice; introduce ideas and suggestions to implement these theories, and present new and emerging paradigms that are set to change graduate medical education in the upcoming decades.

In chapter 4, Organization and Structure of the CTICU, the authors emphasize and describe the team nature of critical care medicine in the Cardiothoracic Intensive Care Unit. The chapter will review the importance of various team members and discuss various staffing models (open vs closed, high intensity vs low intensity, etc.) on patient outcomes and cost. The chapter will also examine the roles of nurse practitioners and physician assistants (NP/PAs) in critical care, and will briefly review the growing role of the tele-ICU. Most studies support the concept that a multi-disciplinary ICU team, led by an intensivist, improves patient outcomes and decreases overall cost of care. The role of the tele-ICU and 24 hour in-house intensivist staffing in improving outcomes is controversial, and more research is needed in this area. Finally, a brief discussion of billing for critical care will be discussed.

The purpose of chapter 5, Palliative Care, is to introduce readers to the specialty of palliative care and its potential benefits for critically ill patients, and to present some of the issues related to the delivery of palliative care in surgical units. Palliative care is a specialty of medicine that focuses on improving quality of life for patients with serious illness and their families. As the limitations of intensive care and the long-term sequelae of critical illness continue to be delimited, the role of palliative care for patients that are unable to achieve their original goals of care, as well as for survivors of critical illness, is changing and expanding.

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In all areas of medicine physicians are confronted with a myriad ethical problems. It is important that intensivists are well versed on ethical issues that commonly arise in the critical care setting. Chapter 6, Ethics, will serve to provide a review of common topics, including informed consent, decision-making capacity, and surrogate decision-making. It will also highlight special circumstances related to cardiac surgical critical care, including ethical concerns associated with emerging technologies in cardiac care.

As discussed in Chapter 7, Acute coronary syndrome (ACS) is a common and sometimes lethal event, usually precipitated by sudden rupture and thrombosis of an atherosclerotic plaque. Patients presenting with ACS can be rapidly risk stratified based on signs, symptoms, electrocardiogram, and biomarkers. There is a new generation of potent and reliable antiplatelet drugs, which in concert with anticoagulation and rapid revascularization, can preserve myocardium and save lives. When choosing how to revascularize, hemodynamically stable patients with diabetes mellitus and complex coronary disease benefit more from coronary artery bypass grafting rather than percutaneous coronary intervention. Despite optimal treatment, ACS can result in deadly complications such as cardiogenic shock. Supportive care is paramount, but despite its widespread use, the utility of intraaortic balloon counterpulsation is uncertain. In the future, advanced coronary imaging may enhance preventative care, novel molecular targets will help expand treatment options, and cell-based regenerative therapies may aid myocardial recovery after acute coronary syndrome.

Valvular heart disease is a common cardiovascular disorder, with an estimated prevalence of 2.5% in the United States. The disease is particularly burdensome in adults over 75 years of age, with 13.3% having moderate to severe disease of the aortic or mitral valve. As populations grow older, diagnostic capabilities improve, and health care becomes more accessible, the number of patients with valvular heart disease undergoing both cardiac and non-cardiac surgery will continue to grow. The preoperative assessment and optimization of these patients is a complex task involving multiple specialists, including internists, cardiologists, intensivists, cardiothoracic surgeons, and anesthesiologists. As newer therapeutic options are offered to patients with numerous comorbidities, the preoperative management of these patients will require a sophisticated multimodal approach. The purpose of chapter 8, Valvular Heart Disease, is to summarize the preoperative assessment and optimization of patients with valvular heart disease undergoing cardiac and non-cardiac surgery.

Advancements in the field of heart failure have significantly improved both mortality and the quality of life of millions. However, heart failure generally remains a chronic disease with an insidious progression to organ failure despite optimal medical treatment. Early consideration of advanced therapies such as mechanical circulatory support and cardiac transplantation in advanced heart failure is essential. The purpose of chapter 9, Heart Failure, is to assist the reader in the identification of patients with advanced heart failure that have not yet developed irreversible end-organ dysfunction, as interventions in this narrow therapeutic window results in improved post-surgical outcomes.

Arrhythmias, low cardiac output syndromes, and low blood pressure are commonly faced complications in the cardiothoracic surgery patient. In order to provide appropriate clinical management, one must identify underlying etiologies while recognizing and understanding available treatment options. The objective of chapter 10, Antiarrhythmics & Inotropes, is to review common agents utilized to manage arrhythmias and maintain hemodynamic stability following cardiac surgery. Mechanisms of action, key clinical pearls and relevant literature pertaining to each agent will be discussed.

There are multiple indications for anticoagulation in the cardiac surgery intensive care unit including cardiac valve replacement, mechanical circulatory pumps (ECMO and ventricular assist devices), deep vein thrombosis prophylaxis, treatment of heparin-induced thrombocytopenia, and treatment of other
thrombotic conditions including pulmonary embolism. Anticoagulant medications broadly fall into two categories: antiplatelet drugs and inhibitors of protein clotting factors. In chapter 11, Anticoagulation Options, the authors review anticoagulant medications, therapeutic drug monitoring, common indications for anticoagulation, and the risks associated with anticoagulation after cardiac surgery.

Patients in the cardiothoracic intensive care unit (CTICU) are subject to numerous physical and mental stresses. While most of these cannot be completely eliminated, intensivists have many tools in their armamentarium to alleviate patients’ pain and suffering. Chapter 12, Sedation and Analgesia, will consider the importance of analgesia and sedation in the CTICU and the relevant consequences of over- or under-treatment. We will examine the tools available for monitoring and titrating analgesia and sedation in critically ill patients. The major classes of medications available will be reviewed, with particular attention to their clinical effects, metabolism and excretion, and hemodynamic characteristics. Lastly, experimental evidence will be assessed regarding the best strategies for treatment of pain and agitation in the CTICU, including use of non-pharmacologic adjuvants.

Chapter 13, Vasodilating Agents, discusses the salient features of arterial and venous dilating agents commonplace in the management of the post-cardiotomy surgical patient. A keen understanding of the underlying cellular mechanism, pharmacology, indication, safety profile, and controversies of clinical utility of vasodilating agents is imperative for routine use. The evidenced-based examination of each therapeutic modality will strengthen the practitioner’s fund of knowledge for management of each pathophysiological state.

Chapter 14, Neurologic Complications in the Cardiac Surgery Patient, discusses the spectrum of complications that occur in the postoperative cardiac surgery patients. It evaluates the mechanistic role of cardiopulmonary bypass and the various cardiac surgical procedures in the development of cerebral injury. Furthermore, it evaluates the role of different intraoperative monitoring in early detection of cerebral injury in these patients. Finally, it provides evidence based practice guidelines for hemodynamic management as well as treatment of complications that are diagnosed in the cardiac surgical intensive care unit.

Clinicians caring for patients with cardio-pulmonary disease invariably must manage the respiratory system. Doing so requires a basic understanding of physiology and the interaction of the heart and lung. Chapter 15, Perioperative Respiratory Care and Complications, begins with rudimentary concepts of respiratory physiology, focusing on, gas exchange, pulmonary mechanics, and cardio-pulmonary interactions. These are used to develop an approach to mechanical ventilation and routine perioperative respiratory care of the patient having undergone a cardio-pulmonary procedure. The final section of this chapter addresses specific respiratory challenges encountered in caring for the critically ill cardiothoracic patient in addition to contemporary management strategies.

Chapter 16, Cardiovascular System addresses underlying physiology, diagnostics, and management of common cardiovascular abnormalities in the patient after cardiac surgery. The goal is to provide insights into daily management, areas of controversy, and future directions in the field. After reviewing basic physiologic principles of cardiac output and circulation; problems affecting the postoperative hemodynamic state will be addressed individually. Specific topics include the low cardiac output syndrome, right ventricular failure, myocardial ischemia, diastolic dysfunction, vasodilatory syndrome, rhythm disturbances, pericardial tamponade, and cardiac arrest. Patients with postoperative open chests, or after orthotopic heart transplantation are also discussed.

The primary goal of chapter 17, Renal, is to provide the reader with an overview of basic renal physiology and function and to review the identification, pathogenesis, and treatment of acute kidney injury
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following cardiac surgery. Particular focus will be directed toward the diagnostic criteria for acute kidney injury, short- and long-term impacts on patient outcomes, role of novel biomarkers, mechanisms of acute renal injury, general management principles, preventative strategies, and the influence of anesthetic and surgical techniques on its development. The content of this chapter will serve to underscore a particularly harmful but likely underappreciated problem affecting patients in the cardiothoracic critical care setting.

Chapter 18 is titled Gastrointestinal. A thorough understanding of gastrointestinal (GI) issues in critical illness is necessary to optimize management of the cardiothoracic patient. Post-operatively, these patients are at increased risk of GI complications due a combination of underlying vascular disease, cardiopulmonary bypass, and low cardiac output, all of which lead to splanchnic hypoperfusion and subsequent damage to the gut mucosa. While GI complications are uncommon, they are associated with a disproportionately high rate of morbidity and mortality. Presence of unexplained fever, leukocytosis, bacteremia, hemodynamic compromise or abdominal pain or distention are concerning and require prompt assessment. Other GI management issues include delivery of adequate nutrition to counteract catabolism and promote wound healing and stress ulcer prophylaxis in patients with risk factors for upper gastrointestinal bleeding.

Infections are a major cause of mortality in intensive care unit (ICU) patients and the most common non-cardiac complications after cardiac surgery. Commonly encountered infections in the cardiothoracic ICU include pneumonia, bloodstream infections, and surgical site infections. At the beginning of this chapter, general measures of infection control and prevention are introduced. Those can help reduce infections and are best implemented in a bundled care fashion. Specifically for ICU patients, care bundles aimed at ventilator-associated pneumonia and central line-associated bloodstream infection have been successfully implemented, studied, and revised. In the next section, antibiotic treatment principles are described. Treatment with antibiotic drugs is an important part of therapy for infectious complications and is under continuous revision given the changing and diverse spectrum of microorganisms and the emergence of multidrug-resistance. In the central part of chapter 19, Infection and Immune System, specific infections are discussed in detail with regards to etiology, incidence, diagnosis, and therapy. Finally, the concept of systemic inflammatory response is described which is a common clinical problem after cardiac surgery, particularly with the use of cardiopulmonary bypass. Several immunologic mechanisms have been found to be associated with this and the clinical picture can be confused with sepsis.

The cardiac perioperative period presents a unique clinical scenario where the risk of life-threatening hemorrhage is balanced against the risk of thrombosis. In chapter 20, Hematology and Transfusion, the authors navigate the complex hemostasis and transfusion issues in cardiac surgery to provide clinicians a comprehensive understanding of the coagulation system in this specialized population. Emphasis is placed on a multidisciplinary team approach focused on risk stratification with preoperative optimization to minimize coagulopathy and bleeding followed by a tailored and conservative use of blood products for maximum patient benefit.

In chapter 21, Endocrine, the authors review several important endocrine disorders frequently encountered in patients undergoing cardiothoracic surgery. Hyperglycemia, common in patients with and without diabetes mellitus (DM) in the perioperative period, has been linked to poor outcomes. Use of an intravenous insulin infusion early in the postoperative course, followed by transition to subcutaneous insulin, with maintenance of moderate glycemic targets (100-180 mg/dL) is currently the standard of care. Oral intake should be encouraged in the postoperative period, but if not possible, nutrition support with enteral nutrition should be considered. Critical illness related corticosteroid insufficiency (CIRCI) should be suspected in critically ill patients with refractory hypotension requiring vasopressors, espe-
cially in the setting of septic shock. Although diagnostic criteria are controversial, if suspected, empiric treatment with corticosteroids should be initiated. Nonthyroidal illness syndrome (NTIS) is common in critically ill patients and thyroid function tests should be interpreted with caution in this population.

Coronary artery bypass grafting (CABG) is one of the most common surgical procedures and the most common cardiac procedures worldwide. It is estimated that over 800,000 CABG surgeries are performed worldwide each year. CABG is a procedure in which one or more stenosed (or occluded) coronary arteries are bypassed with an alternate blood vessel conduit to re-establish normal blood flow to the myocardium. The goals of CABG are to reduce mortality, prevent the progress of heart failure and reduce symptoms associated with coronary artery disease. Chapter 22, Coronary Artery Disease deals with cardiac critical care issues that pertain to the patient undergoing CABG and potential post-operative complications.

Chapter 23, Aortic Valvular Disease discusses valvular stenosis (AS) or regurgitation (AR), but a diseased valve may often exhibit both. The predilection of degenerative disease of the aortic valve, particularly stenosis, for the elderly has resulted in a steadily increasing prevalence as the population ages. As general life expectancy increases in the United States and other western countries, surgery to correct aortic valve disease will increase. As more elderly patients with more comorbidities present for surgery their intraoperative and perioperative care will become more complex. In immediate peri-operative period to facilitate identification and treatment for the practicing intensivist.

Surgery for the mitral valve has increased over the last decade, with a focus on an increasing number of valve repairs for degenerative mitral valve disease. Chapter 24, Mitral Valvular Disease discusses the surgical management of mitral valve disease with a focus on the pathology of mitral valve stenosis and regurgitation. With an examination into the pathophysiology of the lesions. Subsequently a discussion regarding the various surgical techniques for mitral valve surgery followed by the major and minor complications of surgery are reviewed to provide the Intensivist with an overview of possible complications. Finally a look at the future direction of the field is briefly examined.

Thoracic aortic disease most commonly presents in the form of aneurysmal dilation or dissection of the ascending or descending thoracic aorta, most commonly secondary to degenerative disease and hypertension. Several genetic connective tissue disorders are commonly associated as well. Treatment is focused on blood pressure control and surgical repair. Surgical repair of thoracic aortic disease presents unique risks, including neurologic injury involving the brain or spinal cord, and several adjuncts are available to mitigate against this risk. Chapter 25, Thoracic Aorta discusses commonly associated risk factors, preoperative testing, surgical repair, and postoperative management of thoracic aortic disease along with strategies for minimizing neurologic injury.

Orthotopic heart transplantation (OHT) has evolved as the “gold standard” therapy for end stage cardiomyopathy. Advances in the fields of immunosuppression, infection prophylaxis and treatment, surgical techniques as well as intensive care management have transformed heart transplantation from what was once considered an experimental intervention into a standard therapy. Chapter 26, Heart Transplantation focuses on the standard care for OHT including surgical techniques, perioperative management and management of common postoperative complications.

Lung transplantation is a widely accepted surgical procedure for treatment of select patients suffering from end-stage lung disease. Recipients, however, require meticulous post-transplant care to preserve allograft lung function and to ensure optimal patient quality of life. In the post-operative period, these patients are predisposed to specific complications and pose unique considerations that clinicians caring for these patients in the intensive care setting should be familiar with managing. Chapter 27, Lung Trans-
plantation focuses on the early post-operative critical care management of the lung transplant recipient with specific emphasis on hemodynamic resuscitation; early lung graft dysfunction; and considerations regarding immunosuppression and infection. Non-pulmonary issues that affect the clinical care of these patients in the ICU setting are also discussed.

An increasingly important component of the therapeutic armamentarium in the treatment of cardiac and cardiopulmonary pathology, utilization of mechanical circulatory support allows clinicians to help sicker patients with more advanced disease states. A plethora of options exist, each with multiple implant techniques and management strategies. To optimize patient care in a cost-conscious environment, one must understand the advantages and disadvantages of each permutation, and have an algorithmic approach for the selection and application of available technologies. Chapter 28, Mechanical Circulatory Support aims to provide such an understanding by reviewing surgical implant techniques and peri-operative management strategies for a number of commonly used short-term and durable devices.

Patients having major general thoracic surgery constitute an integral part of any cardiothoracic intensive care unit. Pulmonary or esophageal resection especially in a patient who has cardiopulmonary issues at baseline demands close monitoring by a critical care team postoperatively. Chapter 29, Thoracic Surgery aims to cover the important aspects of the perioperative care involved with these patients. In addition, procedures requiring an intensive care unit postoperatively such as, pneumonectomy, esophagectomy, thymectomy are dealt with in some detail where key technical aspects and care and complications specific to each are discussed.

Chapter 30, Physiologic Monitoring will provide a review of modern concepts of cardiovascular monitoring with emphasis on essential hemodynamic variables in the early post cardiac surgery patient. When defining circulatory function, importance of the entire circulatory system is underscored. This includes the function and interaction of the heart, blood vessels and circulatory blood volume to deliver sufficient amount of oxygenated blood to tissue beds. In post cardiac surgery patients, the pulmonary artery catheter remains the most widely used technology to assess cardiac function. This chapter highlights the importance of validation of less invasive and noninvasive hemodynamic monitors for the management of critically ill patients and early post cardiac surgery patients. In addition, this chapter describes the evolution of monitoring of post cardiac surgery and critically ill patients, examines different monitoring technologies and address controversial questions in modern practice as well as future directions.

Bleeding in the postoperative cardiac surgical patient can be multifactorial. Chapter 31, Coagulation Monitoring examines the preoperative and intraoperative risk factors for having significant postoperative bleeding. It also discuss the advantages and disadvantages of standard laboratory testing as well as point-of-care tests, such as thromboelastography (TEG) and thromboelastometry (ROTEM), in their diagnostic capabilities. Finally, we conclude with different treatment strategies in this challenging patient population along with diagnostic criteria of clinically significant postoperative bleeding and when to return to the operating room for reexploration.

Sonography in the intensive care unit is a rapidly emerging point-of-care diagnostic tool. Literature supports the use of sonography for the evaluation of lung pathology, protocol based focused cardiac evaluation, and abdominal pathology, as well as identifying deep venous thrombosis. There is also evidence that ultrasound guided procedures such as venous access, thoracentesis, and paracentesis may decrease complications compared to a landmark based technique. However, there is ambiguity in the literature regarding definition, scope, and training in this modality as used by intensivists. The purpose of chapter 32, Echocardiography and Ultrasound in the Intensive Care unit is to provide a broad overview of the role of ultrasound in the ICU and data supporting the use of point-of-care protocols. This chapter does
not provide instruction on how to perform a complete transthoracic or transesophageal exam, nor does it provide a library of images of various pathologies since a reader seeking such depth would be better served by a full textbook on echocardiography.

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We hope you enjoy reading!

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