IMPROVING OUTCOMES IN COLON AND RECTAL SURGERY

EDITED BY

BRIAN R. KANN • DAVID E. BECK • DAVID A. MARGOLIN
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Preface

Quality measures and outcomes are receiving greater attention by the lay and medical communities. The occurrence or mismanagement of complications often results in poor outcomes, increased cost, and significant morbidity. Answering the call for transparency and improvement requires action by all involved in the care of patients. Collection of objective data and quality measures allows documentation of optimal care and desired outcomes while identifying areas for improvement.

The goal of this book is to present the current knowledge of outcomes, as well as the techniques for minimizing and managing complications from the common diseases and procedures of this specialty. This information will aid providers in optimizing care and encourage research in outcome and quality measurement.

Improving Outcomes of Colon and Rectal Surgery represents the collaborative efforts of many individuals. The contributing authors were selected for their knowledge of colorectal surgery and ability to present their surgical judgment and experience in written form. They represent a spectrum of experienced providers who have made significant contributions to younger individuals who will shape the future of their specialty. In addition to reviewing the available literature, they have described their personal approach to complications in colorectal surgery. Numerous technical descriptions and highlights from multiple discussions held in surgical locker rooms, morbidity and mortality conferences, and the hallways of conferences and symposiums have been included. Using this approach, we hope this book will provide initial guidance to the less-experienced provider and stimulate additional thought and research to the more-experienced provider.

The editors gratefully acknowledge the efforts of the many individuals who made this book possible. This book carries on the vision of previous editors and contributors to the first two editions of *Complications in Colon and Rectal Surgery* and *Improved Outcomes in Colon and Rectal Surgery*.

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Brian R. Kann, MD, FACS, FASCRS earned his undergraduate degree from Old Dominion University in Norfolk, VA in 1993, followed by his medical degree from Hahnemann University in Philadelphia, PA in 1997. He completed his internship and residency in general surgery, including a one-year research fellowship focusing on transplant immunology, at Cooper University Hospital, University of Medicine and Dentistry of New Jersey (UMDNJ)/Robert Wood Johnson Medical School in Camden, New Jersey in 2003, then went on to complete a residency in colon and rectal surgery at the Ochsner Clinic in New Orleans, Louisiana in 2004. He has previously held academic appointments at Cooper University Hospital, UMDNJ/Robert Wood Johnson Medical School, where he was assistant professor of surgery and program director of the General Surgery Residency from 2004 to 2010, and at the University of Pennsylvania Perelman School of Medicine, where he was assistant professor of clinical surgery and program director of the Colon and Rectal Surgery Residency from 2010 to 2014. In 2015, he returned to the Ochsner Clinic in New Orleans, where he currently serves as a senior staff surgeon and associate program director of the Colon and Rectal Surgery Residency.

Dr. Kann is certified by both the American Board of Surgery and the American Board of Colon and Rectal Surgery. He is an active member of the American College of Surgeons, the American Society of Colon and Rectal Surgeons (ASCRS), the Association of Program Directors in Colon and Rectal Surgery, and the Society for Surgery of the Alimentary Tract. He has served on numerous committees within these organizations and has been selected as program chair for 2019 ASCRS national meeting. He has published numerous original scientific manuscripts, reviews, and book chapters in the field of colon and rectal surgery. While his practice spans the field of colon and rectal surgery, he has particular clinical interest in the surgical management of inflammatory bowel disease.

David E. Beck, MD, FACS, FASCRS was a distinguished graduate of the United States Air Force (USAF) Academy and attended medical school at the University of Miami. He completed his residency in general surgery at Wilford Hall USAF Medical School, Lackland AFB, Texas and completed a fellowship in colorectal surgery at the Cleveland Clinic Foundation, Cleveland, Ohio. He is board certified in general and colon and rectal surgery and is a fellow of the American College of Surgeons and the American Society of Colon and Rectal Surgeons. After retiring from the Air Force, where he was chairman and residency program director of the Department of General Surgery at Wilford Hall USAF Medical Center and the military consultant to the air force surgeon general in colon and rectal surgery, Dr. Beck joined Ochsner in 1993, served as chairman of the Colon and Rectal Surgery Department from 1995 to 2014, and is now chairman emeritus.

Dr. Beck conducts research on colorectal diseases, has authored and edited nine medical textbooks, and written over 300 scientific publications. He was the president of the American Society of Colon and Rectal Surgeons (ASCRS) from 2010 to 2011 and is a member of many other medical associations. He served as a member of the Board of Governors of the Ochsner Clinic Foundation from 2005 to 2012 and currently serves on the American Board of Colon and Rectal Surgery. Dr. Beck is on the editorial board of several prestigious medical journals. In addition to his clinical and administrative duties, he is a professor of surgery at the University of Queensland, Australia and is on the clinical faculty at the Louisiana State University and Uniformed Services University Schools of Medicine. Dr. Beck is listed in Who's Who, Best Doctors in America, Good Housekeeping's Top Cancer Doctors for Women, and Best Surgeons in New Orleans. Dr. Beck is a nationally recognized expert in inflammatory bowel disease, anal, rectal

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David A. Margolin, MD, FACS, FASCRS earned his medical degree from the Medical College of Ohio in Toledo and completed his internship and residency at Case Western Reserve University in Cleveland, Ohio. He completed his fellowship in colon and rectal surgery at Ochsner. Dr. Margolin is board certified in general surgery and colon and rectal surgery and has been on staff at Ochsner since the beginning of 2003. Dr. Margolin is te current President of the American Society of Colon and Rectal Surgeons and is listed in Best Doctors in America. He serves as Director of Colon and Rectal Surgery Research. His professional interests include laparoscopic colon and rectal surgery, inflammatory bowel disease, complex anorectal conditions and incontinence.

H. David Vargas, MD, FACS, FASCRS graduated with distinction with a major in Religious Studies from the University of Virginia in Charlottesville, Virginia. He stayed at the University of Virginia and graduated from the School of Medicine. He completed a residency in General Surgery and served as Chief Surgical Resident at the Lehigh Valley Hospital in Allentown Pennsylvania. Dr. Vargas then pursued additional training here in New Orleans performing a fellowship at the Ochsner Clinic in the specialty of Colon Rectal Surgery. He became board certified (and has been re-certified) by the American Board of Surgery and the American Board of Colon Rectal Surgery. Of note, Dr. Vargas distinguished himself by attaining the highest score on the written examination administered by the American Board of Colon and Rectal Surgery.

After leaving fellowship training in New Orleans, Dr. Vargas gained extensive clinical experience in both private practice and academic surgery all the while remaining involved in medical education and postgraduate surgery resident training. He has been active in local, regional, and national professional organizations and has held positions of leadership. He has authored multiple book chapters as well as scientific articles published in peer-reviewed surgical journals.

While Dr. Vargas' clinical practice encompasses the breadth of Colon Rectal Surgery, in particular he has gained recognition for minimally invasive or laparoscopic colorectal surgery which led to his recruitment in 2007 to the University of Kentucky College of Medicine as Chief of Colon Rectal Surgery.

After five years in Kentucky, he returned to New Orleans in 2012 and joined the Department of Colon and Rectal Surgery of the Ochsner Clinic where he now serves as Staff Surgeon and Program Director of the Colon Rectal Surgery Fellowship. In addition, he is a Assistant Medical Director of Endoscopy Services at Ochsner Medical Center.

Charles B. Whitlow, MD, FACS, FASCRS earned his medical degree from the University of Arkansas and completed his internship and residency at William Beaumont Army Medical Center in El Paso, Texas. He completed his colon and rectal surgery fellowship at Ochsner. Dr. Whitlow is board certified in general surgery and colon and rectal surgery and has been on staff at Ochsner since the Summer of 2002. Dr. Whitlow is the chairman of the Department of Colon and Rectal Surgeins. He is listed in Best Doctors in America and is a Past President of the American Board of Colon and Rectal Surgery. His particular areas of professional interest include transanal excision of large benign rectal tumors, sphincter-preserving surgery for rectal cancer, surgical treatment of inflammatory bowel disease, laparoscopic and robotic colon and rectal surgery, surgery for rectal prolapse, and treatment of anorectal fistulas.

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Preexisting conditions

ARIDA SIRIPONG AND FAROUQ MANJI

CHALLENGING CASE

A 63-year-old woman is referred to your office with a right colon cancer found on screening colonoscopy. Her past medical history is significant for stable coronary artery disease.

CASE MANAGEMENT

You order a complete blood count (CBC) and basic metabolic profile. A chest x-ray and a computed tomography (CT) scan of the abdomen and pelvis are obtained for staging purposes. No other workup is needed prior to scheduling the patient for surgery.

INTRODUCTION

A thorough preoperative assessment is essential to identify, treat, and optimize preexisting comorbidities and minimize morbidity and mortality after colorectal surgery. Paying early attention to patient risk factors and recognizing their potential impact on outcomes is the surgeon's responsibility. This will often require a multidisciplinary approach and coordination with other physicians; however, these extra steps and dedicated attention are as critical as the technical aspects of the procedure to ensure maximal benefit for each patient.

This chapter highlights preoperative optimization of the patient undergoing elective colorectal surgery. In the setting of emergent surgery, additional testing or modification of preexisting conditions is a luxury, and the risk of delaying surgery will seldom justify the benefit of additional workup. In these cases, intensive intraoperative and perioperative care is necessary to minimize complications.

PREOPERATIVE TESTING

For healthy patients undergoing surgery, routine laboratory tests may be unnecessary. In a large study of 2,000 patients undergoing elective surgery, only 0.22% of routine preoperative laboratory results found abnormalities that prompted intervention (1). This testing can unnecessarily delay surgery and lead to an increase in health-care costs without clinical benefit. Therefore, the decision to order preoperative tests in the healthy individual should be guided by the patient's clinical history, physical exam findings, disease pathology, and risk of planned surgery.

Ambulatory anorectal procedures are considered low risk and do not require routine laboratory testing in the asymptomatic patient (2). The remaining colorectal procedures, however, generally involve intraabdominal dissection and are classified as elevated risk. Baseline blood count and type and screen are indicated in these patients undergoing major surgery where significant blood loss is a potentiality and/or is anticipated. Coagulation studies are reserved for patients with a history of bleeding or coagulopathy, on chronic anticoagulation medications, or with comorbidities that may affect normal coagulation (renal disease or liver failure). Creatinine level is warranted in older patients (older than 60 years old), as well as in those with a history of diabetes or baseline renal insufficiency. Patients with recent weight loss, infection, or hospital admission may benefit from albumin assessment to guide recommendations for preoperative nutritional support and discussion regarding the role of stoma creation.

CARDIAC EVALUATION

Cardiovascular disease (CVD) is the leading cause of death in the industrialized world (3), and 25%–30% of all patients undergoing noncardiac surgery have significant coronary artery disease at the time of operation (4). The goal of preoperative cardiac evaluation is to identify those who will

benefit from additional testing and intervention prior to surgery. In general, prophylactic cardiac interventions are not advised, and additional workup should only be recommended if also warranted outside of the surgical setting.

Perioperative risk stratification for noncardiac surgical patients is calculated based on procedure-related risk, cardiac risk indices, and assessment of exercise tolerance based on metabolic equivalents (METs). Currently the American College of Cardiology/American Heart Association (ACC/AHA) categorizes noncardiac surgery into *low risk*, which conveys a risk of myocardial infarction or major adverse cardiac event (MACE) <1%, and *elevated risk*, which conveys risk ≥1% (5). Historically, this risk was stratified into three groups; however, recommendations for those of intermediate and high risk were similar. Therefore, in current guidelines, these groups have been combined and most major colorectal procedures are classified as elevated risk.

Various cardiac risk indices have been described. The Goldman Cardiac Risk Index is a multivariate risk index and precursor to the widely used Lee Revised Cardiac Risk Index (RCRI) (6,7). The RCRI is a simple and validated evaluation tool, based on six predictors of perioperative cardiac risk (high-risk surgery, history of ischemic heart disease, congestive heart failure, cerebrovascular disease, diabetes mellitus requiring insulin treatment, and renal dysfunction with creatinine >2). A patient with none, one, two, or more than three risk factors has a MACE rate of 0.4%, 1.0%, 2.4%, and 5.4%, respectively (6). The American College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) Myocardial Infarction and Cardiac Arrest (MICA) Risk Calculator is a tool based on multivariate analysis, derived from prospectively collected data from over 500 hospitals and one million operations (8). The advantage of the NSQIP calculator is the greater number of input variables required to generate risk estimations, therefore deriving more accurate results. MICA has been shown to outperform the RCRI in discriminative power among the same group of patients (8). Regardless of which model is chosen, practitioners should be comfortable using one of these risk indices in the preoperative assessment.

The recommended 2014 ACA/AHA algorithm for preoperative cardiac evaluation is shown in Figure 1.1 (5). As previously noted, patients needing emergent surgery require close perioperative monitoring and management but often cannot delay surgery for additional testing. Those with acute coronary symptoms undergoing nonemergent surgery should be treated based on guideline-directed medical therapy (GDMT). Asymptomatic patients with cardiac risk factors are stratified based on surgical and clinical risk. Low-risk procedures do not require additional testing, whereas those undergoing elevated-risk procedures are further categorized based on METs. METs, a measure of exercise tolerance, can be evaluated based on a few simple questions during the initial encounter. Patients unable to walk two blocks on level ground or carry two bags of groceries up one flight of stairs without symptoms of angina or dyspnea have poor exercise tolerance, equivalent to <4 METs. The role of cardiac stress testing is closely related to METs and functional capacity of the patient. Patients with elevated surgical risk and poor (<4 METs) or unknown functional capacity should undergo exercise or pharmacological stress testing if it will change management. In the setting of elective surgery, findings of severe cardiac ischemia on stress testing should prompt intervention with medical therapy and/or preoperative revascularization. Of note, in those with <4 METs, additional cardiac testing or intervention should not be pursued if it will not impact surgical decision-making (decision to proceed with surgery or palliative measures).

TESTING AND INTERVENTIONS

As mentioned previously, prophylactic cardiac interventions have no proven benefit in outcomes and should only be considered in patients who would also require it in the nonsurgical setting (5). In those who present with indications for urgent cardiac intervention before noncardiac surgery, the type of cardiac intervention should be guided by the urgency of the noncardiac surgery.

Coronary artery bypass graft (CABG) is indicated in patients with triple vessel disease or myocardial ischemia with concomitant decreased left ventricular function, who require elective noncardiac surgery with a high bleeding risk (9). There is a paucity of data regarding optimal timing of elective noncardiac surgery after CABG, although one compelling study suggests a significant increase in mortality for patients undergoing high-risk vascular surgery within 30 days of CABG (10). Therefore, when possible, noncardiac surgery should be postponed for 30 days after recent CABG and may not be a feasible option for the patient with symptomatic colorectal pathology.

Percutaneous coronary intervention (PCI) with drug-eluting or bare metal stents is indicated in (1) patients with left main disease whose comorbidities preclude bypass surgery without undue risk and (2) patients with unstable coronary artery disease who would be appropriate candidates for emergency or urgent revascularization (11,12). While bare metal stents require uninterrupted antiplatelet therapy for 30 days, this recommendation is extended to 365 days after placement of a drug-eluting stent. These recommendations are based on several studies that show convincing evidence that disruption of dual-antiplatelet therapy within a short time period results in higher adverse cardiac outcomes, and is the leading predictor of coronary thrombosis and restenosis (13,14). In the setting of a recent stent and urgent indications for major abdominal surgery, discussion with the patient's cardiologist regarding the use of bridging antiplatelet agents, such as Integrillin or Tirofiban, may be beneficial (15). When used as a bridging agent for Plavix, these short-acting agents should be started as an infusion therapy 24 hours after the last dose of Plavix (5 days prior to surgery) and continued up to 4 hours prior to surgery. The infusion is then resumed 2 hours postoperatively until Plavix is restarted.

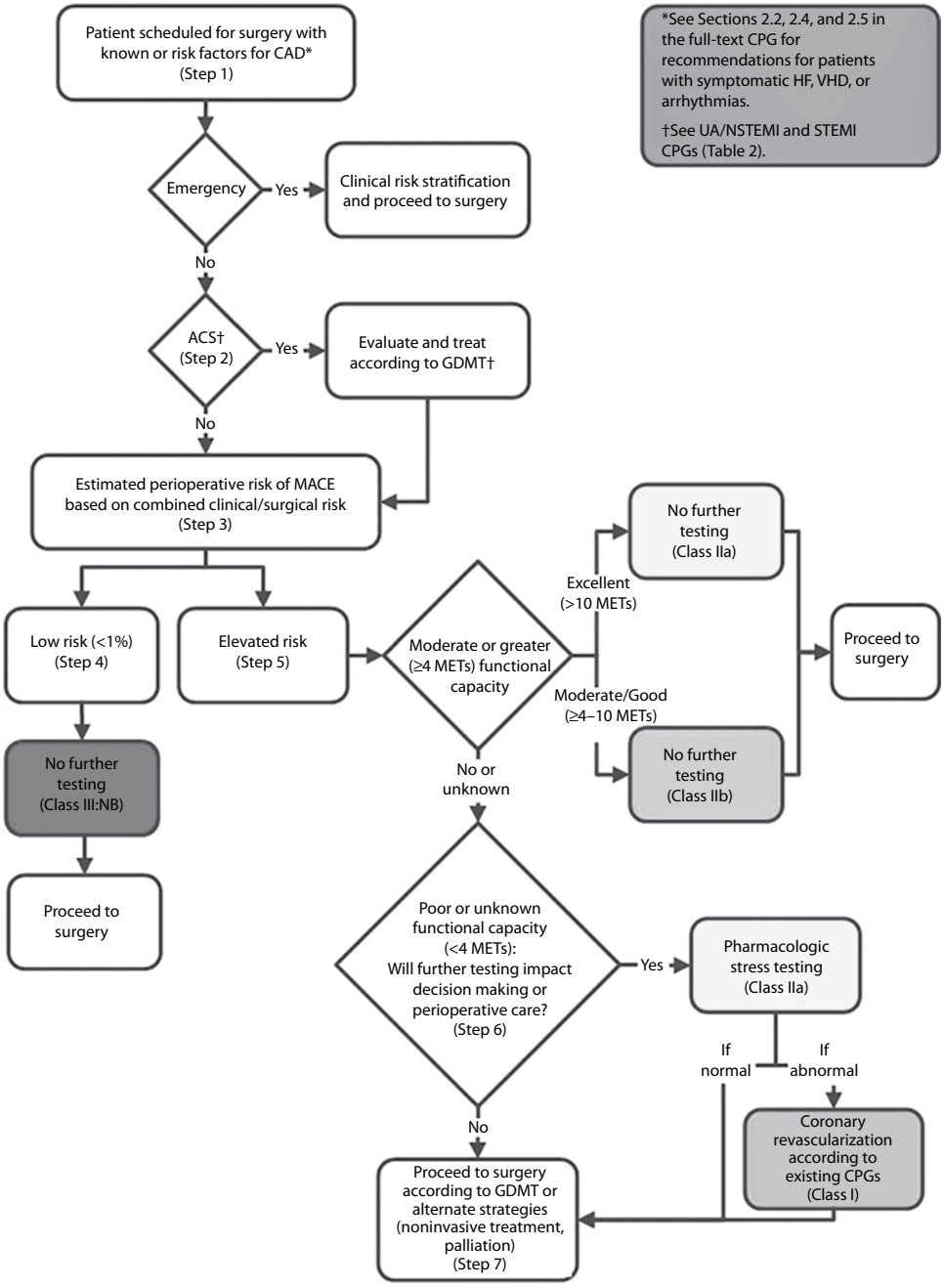

Figure 1.1 ACC/AHA cardiac risk assessment algorithm. (Data from Fleisher LA et al. *Circulation*. 2014;130(24):2215–45.)

Balloon angioplasty should be considered for those who do not meet criteria for CABG, require time-sensitive noncardiac surgery, and/or are at high risk for bleeding (16). A patient with a new diagnosis of colon cancer with findings of severe cardiac ischemia may fall into this category. The main benefit of balloon angioplasty is the ability to carry out noncardiac surgery immediately without necessitating dual-antiplatelet therapy, although ideally such surgery should be postponed a minimum of 14 days (5). Ultimately, decisions regarding type of PCI and management of perioperative antiplatelet therapy should be coordinated between the surgeon, cardiologist, anesthesiologist, and patient, weighing the relative risk of bleeding versus stent thrombosis.

PERIOPERATIVE β-BLOCKADE

β-Blockers should be continued in patients who were using them chronically, and postoperative management should be guided by clinical circumstances, such as hypotension, bradycardia, or bleeding (5). In patients at intermediate or high risk of myocardial ischemia, or with three or more RCRI factors, it may be reasonable to start β-blockers in the preoperative setting. Importantly, though, β-blockers should be initiated in advance of surgery to assess safety and titrate dosage appropriately. β-Blockers should not be started on the day of surgery, and this may actually be harmful, as illustrated by results of the POISE (Perioperative Ischemic

Evaluation Study) trial (17). In this study of 9,000 participants, although β-blockade diminished the incidence of myocardial infarction, patients also experienced higher rates of death, stroke, hypotension, and bradycardia.

PULMONARY ASSESSMENT

Postoperative pulmonary complications (PPCs) are common after noncardiac surgery and play an important role in patient outcomes. Definitions of PPCs vary across studies, and therefore, the true incidence is difficult to describe, with reported rates ranging from 6% to 80% (18). Patient-related factors that increase risk of PPCs include smoking, age older than 60 years, congestive heart failure, chronic obstructive pulmonary disease (COPD), functional dependency, and American Society of Anesthesiologists (ASA) Physical Status Classification of III or above (18–20). Surgery-specific factors include general anesthesia, longer operating room times (more than 2–3 hours), emergency surgery, and site-specific surgery, with the greatest risk among upper abdominal and thoracic procedures, which contribute to splinting and a restrictive pulmonary physiology (21,22). In a recent multicenter prospective study of ASA III patients undergoing prolonged general anesthesia (more than 2 hours), 33.4% of patients experienced at least one PPC. In this study, even mild PPCs, including atelectasis or prolonged oxygen requirement, were predictors of increased mortality, intensive care unit admission, and prolonged length of stay. Furthermore, modifiable factors from this review included colloid administration, higher intraoperative blood loss, prolonged surgery and anesthesia time, and higher intraoperative tidal volumes (18).

COPD is a significant predictor for pulmonary complications, with an observational study based on the NSQIP database describing risk of pneumonia, prolonged ventilation, and reintubation at 6.5%, 8.8%, and 5.5% among COPD patients (23). However, despite the increased risk seen in COPD patients, there is no prohibitive level of pulmonary function that serves as a contraindication to noncardiac surgery. Prior studies demonstrate that COPD severity does not incrementally correlate with risk of PPCs; therefore, routine spirometry is also not recommended in COPD patients without clinical changes in pulmonary function (21).

Smoking is widely accepted as a risk factor for PPC. Rates of respiratory failure, pneumonia, and other related complications are demonstrably higher in active smokers (24–26). These patients are more likely to have prolonged hospital stay, obtain wound infections, and experience venous emboli and cardiac complications (27–29). Thus, patients should be screened for smoking status, previous smoking history, and in specific cases, occupational or secondhand exposure. Prior debate centered on the duration of smoking cessation before intervention and the potential increase in PPC if patients stop smoking shortly before surgery. This was based on a small study published in 1989, which suggested PPCs could be higher in patients who cease smoking less than 8 weeks before surgery versus those who continue smoking (30). More recent analysis, however, challenges these results. Two recent meta-analyses demonstrate no evidence to suggest an increased risk of PPC when smoking cessation occurs within a few weeks of surgery. Furthermore, there is a time-related decrease in postoperative complications the longer smoking is stopped before surgery (31,32). The current data demonstrate that it is safe to encourage patients to stop smoking any time in the preoperative period, and ideally 6–8 weeks before the procedure.

Obstructive sleep apnea (OSA) is defined by a state of upper airway obstruction leading to apneic episodes. The incidence of OSA has increased with the rise in obesity and is associated with higher risk of postoperative hypoxemia, cardiopulmonary events, intensive care unit admission, and increased hospital length of stay (33). Unfortunately, OSA may be undetected in the preoperative setting, as symptoms may deviate from the traditional description of daytime sleepiness and snoring, and instead manifest as headaches, difficulty concentrating, altered mood, and nocturia. Given the challenges in diagnosing OSA based on symptoms alone, screening tools including the STOP-Bang questionnaire have helped identify patients who may benefit from pulmonary evaluation prior to major abdominal surgery (34). This questionnaire includes four objective patient measures and four additional questions regarding sleeping habits. Preoperative recognition of OSA can minimize anesthetic complications as well as PPC with the anticipated use of continuous positive airway pressure postoperatively.

Guidelines regarding preoperative chest radiography and spirometry emphasize clinical assessment, relying on the history and physical exam (21). Guidelines from the American College of Physicians do not recommend routine preoperative chest radiography for predicting risk of PPC, as it does not alter outcomes (35). Patients who should have chest radiography include those with new or unstable cardiopulmonary signs or symptoms, and patients at increased risk of postoperative pulmonary complication if the results would alter perioperative management (i.e., informed decision-making, timing, and type/technique of surgery). For example, a COPD patient diagnosed with pneumonia on chest x-ray may benefit from delaying elective surgery until the infectious process is treated and pulmonary status is optimized to baseline.

RENAL DISEASE

Chronic renal failure is present in over 20% of patients over the age of 60, and is reported in 15% of the population overall (36). Renal failure encompasses a wide range of kidney dysfunction, ranging from glomerular filtration rate <60 mL/min to dialysis-dependent renal failure. Regardless of disease severity, it is crucial to prevent additional kidney

injury in these patients who are highly susceptible to postoperative acute renal failure. Intraoperatively, significant blood loss and hypovolemia are poorly tolerated and should be minimized. Avoidance of nephrotoxic agents, including nonsteroidal anti-inflammatory agents and IV contrast, and recognizing the impact of decreased renal function on medication clearance, such as nondepolarizing neuromuscular blocking agents, are critical components to perioperative care.

Chronic kidney disease is associated with a host of comorbidities, but most significantly it increases risk of CVD and is an independent predictor of adverse cardiac events. CVD and kidney disease are closely related, and in the nonsurgical setting, CVD is the leading cause of morbidity and mortality in chronic renal failure patients. Postoperatively, these patients experience a higher rate of cardiovascular complications and noncancer mortality after colorectal cancer surgery; the rate in this population has been reported at 5%–10% after elective and up to 40% after emergency procedures (37). Given this relationship between CVD and chronic kidney disease, there should a high index of suspicion for underlying cardiac disease in all renal failure patients.

In end-stage renal failure, surgery should be timed soon after dialysis to minimize electrolyte and fluid shift changes. Prior to surgery, it is also important to recognize the physiologic changes that accompany underlying chronic kidney disease. Progressive renal disease can lead to hypoalbuminemia, anemia, hyperkalemia, decreased leukocyte and immunologic function, and increased bleeding time due to uremic platelet dysfunction. These changes contribute to higher rates of infectious and wound complications in this population and should be carefully considered and discussed with the patient when consenting for surgery. As coagulopathy is secondary to platelet dysfunction in the uremic patient, in the emergent setting, DDAVP (desmopressin acetate) or dialysis may be used to mitigate bleeding complications.

LIVER DISEASE

Cirrhosis and underlying liver disease represent the most significant predictors of mortality after colorectal surgery, noting a 6.5-fold increased risk (38). Fortunately, it is rare for patients to present with colorectal disease in the setting of cirrhosis. For these unique situations, it is critical to consider the natural history of the colorectal pathology, the severity of liver dysfunction, and potential candidacy for liver transplantation. Thorough preoperative counseling facilitates informed decision-making, allowing the surgeon to review goals of care and outline realistic expectations regarding risks of any intervention.

Liver failure is a well-known predictor of mortality after abdominal surgery. Two available metrics, the Child-Turcotte-Pugh (CTP) and Model for End-Stage Liver Disease (MELD) scores, are used to assess surgical risk in liver failure patients. The CTP classification was originally described to assess operative risk in patients undergoing shunt surgery for portal hypertension but has also been utilized in risk assessment for other abdominal surgeries (39). Designed to quantify liver dysfunction, the CTP score uses albumin, bilirubin, prothrombin time (INR), presence of ascites, and encephalopathy to assign points and subsequently classify patients into three categories, A–C (maximal dysfunction). Mortality associated with Child's class A, B, and C has been reported at 10%, 17%, and 63% (40), respectively, in a review of nonhepatic abdominal procedures. In a study of cirrhotic patients undergoing colectomy, in-hospital mortality was 24%, with the highest mortality rates in those with encephalopathy, ascites, hypoalbuminemia, and anemia (38). The MELD score is derived from a complex formula based on INR, bilirubin, and creatinine and is calculated using Web-based tools. In general, MELD scores classified as less than 10, 10–15, and greater than 15 correlate to Child's class A, B, and C, respectively. MELD scores greater than 15 have been associated with a higher risk of complications, mortality due to complications, and overall mortality after colorectal surgery (41).

Postoperative morbidity in the cirrhotic patient is largely related to anastomotic, bleeding, and stoma complications (42). Damaged hepatocytes decrease production of clotting factors, with subsequent coagulopathy, and preoperative anticipation of bleeding risk is critical. Although minimizing the severity of a significant anastomotic leak, stoma creation in the setting of ascites has inherent risks of peristomal leakage and varices as well. Furthermore, ascites can increase infectious complications, wound dehiscence, or evisceration. Meunier evaluated 41 cirrhotic patients who underwent colorectal surgery and identified postoperative infection as the most significant risk factor for mortality, increasing it from 11% to 53% (43).

Preoperative findings, such as portal hypertension, varices, and a large amount of ascites, represent decompensated liver failure and may be an indication to consider preoperative transjugular intrahepatic portosystemic shunt (TIPS), if colectomy is deemed necessary. One study of severely cirrhotic patients with abdominal malignancies reported outcomes of abdominal surgery 1 month after TIPS was performed, noting decreased portal hypertension, ascites, and venous congestion; less intraoperative blood loss; and decreased need for blood transfusion (44). Nonetheless, TIPS increases the rate and severity of hepatic encephalopathy, and 1-year mortality rate after TIPS is estimated at 50%, related to the overwhelming severity of liver failure. Regardless of whether or not TIPS is pursued, medical optimization of ascites with diuretic agents should also be employed throughout the perioperative period to minimize fluid overload.

A rare but significant dilemma arises when a cirrhotic patient presents with colorectal cancer. It is important to remember that a cirrhotic patient will not be a transplant candidate until deemed cancer free for 5 years. These

cases should be discussed in a multidisciplinary setting, to review overall goals of care, both short and long term. Nonetheless, metastatic colorectal cancer to the liver is low (<10%), with theorized low rates due to poor tissue environment for tumor growth (45). Given the host of physiologic changes that accompany this disease process, patients with liver failure present several perioperative challenges.

DIABETES

In 2012, it was estimated that 29.1 million people in the United States had diabetes, with approximately 20% (8.1 million) of patients undiagnosed (46). Diabetic patients harbor microvascular and macrovascular pathology that contribute to long-term complications, including nephropathy, CVD, cerebrovascular disease, neuropathy, and retinopathy and have been associated with increased morbidity and mortality after colorectal surgery (47). This increase in complications is likely a manifestation of both hyperglycemia and the associated comorbid conditions, with higher rates of postoperative renal failure and myocardial infarction identified in diabetic patients (48).

Surgery induces a physiologic disruption in glucose homeostasis due to release of stress hormones and insulin resistance. For diabetic patients, who have marginal insulin secretion at baseline, the above factors contribute to a significant catabolic state. The subsequent hyperglycemia is a well-described risk factor for delayed wound healing and infectious complications after colorectal surgery. Hyperglycemia impairs monocyte and neutrophil function, with a resultant increase in surgical site infections (49–51). In a review of 11,633 general surgery patients undergoing colorectal and bariatric surgeries, hyperglycemia (>180 mg/dL) was associated with adverse infectious complications, with effects mitigated in those who received insulin (52). Close glycemic monitoring, however, is critical to prevent and treat not only hyperglycemia but also *hypo*glycemia. Prolonged hypoglycemia can lead to neurologic sequelae, including somnolence, unconsciousness, seizures, and irreversible neurologic damage (53), and play an equally detrimental role in the recovery period.

Hemoglobin A1c serves as an indicator of global long-term glucose control, and studies suggest a relationship between preoperative levels and postoperative morbidity (54). A prospective study of 438 patients undergoing abdominal surgery reported higher rates of major postoperative complications in those with preoperative HbA1c levels >6.5% and perioperative hyperglycemia (54). Similarly, Gustaffson and colleagues reported increased morbidity after colorectal surgery in patients with HbA1c >6 mg/dL (55). Although firm guidelines do not exist regarding optimal preoperative levels, a recent HbA1c level should be obtained prior to surgery to optimize glycemic control leading up to elective procedures.

OBESITY

Based on the most recent data from the Centers for Disease Control and Prevention, 38% of the adult U.S. population is obese, defined as body mass index (BMI) >30 kg/m^2 (56). Furthermore, more than 5% of men and 10% of women are classified as morbidly obese, with BMI >40 kg/m^2. The obesity epidemic places a significant socioeconomic burden on our health-care system and predisposes patients to additional comorbidities, including insulin resistance and diabetes, CVD, hypertension, and obstructive sleep apnea (57,58).

Physically, these patients pose specific technical challenges for the colorectal surgeon, and the obese patient significantly benefits from a minimally invasive approach when feasible (59). Despite these technical challenges, obese patients have a decreased mortality rate compared to their nonobese counterparts, referred to as the "obesity paradox" (60). This favorable outcome is thought to be a result of increased nutritional stores and a chronically inflamed state of obesity that may better prepare these patients for the physiological stress of surgery.

Despite this lower mortality rate, obese patients harbor a prothrombotic and pro-inflammatory state and experience increased morbidity after colorectal surgery, with higher rates of venous thromboembolism (VTE) and surgical site infection (SSI). In a study of 7,020 colectomy patients, obese patients had an increased rate of SSI compared with nonobese patients (14.5% versus 9.5%, $p < 0.001$) and overall increased risk of SSI by 60% (61). In addition, obese patients demonstrate a significantly increased risk of pulmonary embolism (2.18; 95% confidence interval [CI], 2.16–2.19) and deep vein thrombosis (relative risk [RR] 2.5; 95% CI, 2.49–2.51), with these results magnified in those under the age of 40 (62). Measures to decrease VTE and infectious complications in the obese population may include patient selection for secondary or delayed primary closure and consideration for extended thromboprophylaxis, in the section "Considerations for Extended Thromboprophylaxis".

MALNUTRITION

One of the most important yet often underrecognized factors to assess at the initial encounter is nutritional status. Malnutrition is common among colorectal cancer patients, and it is a well-known predictor of postoperative complications (63). Furthermore, obstruction, fistulization, and infection related to inflammatory bowel disease (IBD) or malignancy can prevent adequate nutrient and fluid absorption. Therefore, strategies to optimize nutrition are a critical component of preoperative planning.

Malnutrition is a well-known predictor of adverse postoperative outcomes after colorectal surgery and is traditionally defined by an albumin level 3.5 g/dL, BMI <18.5 kg/m^2, or weight loss of >10% of total body weight over a 6-month

period. A recent review of the ACS NSQIP database showed a high rate of malnutrition in colorectal cancer patients (27.8%), much higher than all other cancer types (64). In this study, the three listed criteria were used to define malnutrition, but only albumin <3.5 g/dL independently predicted 30-day mortality and postoperative outcomes including sepsis, renal failure, and cardiovascular events, return to operating room, and need for reintubation. In reality, however, several factors can affect fluctuations in albumin level, and it should not be taken as a sole indicator of nutritional status and the implied risks.

When identified, malnutrition should be addressed and treated in the nonemergent setting. In the last two decades, the role of immune-enhancing nutritional supplementation, or immunonutrition (IMN), has been well studied with promising results from several randomized controlled trials. These formulas are composed of specific immune-modulating substances, including arginine, nucleotides, glutamine, and omega-3 fatty acids/fish oil, which have been shown to modify postsurgical stress and immune response, resulting in lower infectious complications and shorter length of stay (65). Arginine is an essential amino acid found at low resting levels in the normal state, but serves as the primary fuel source for T cells. During trauma or surgery, arginine production cannot meet the demands of the body; therefore, IMN can significantly support immune function by supplementing this deficiency.

Even a short course of high arginine-rich protein and nutrient supplements prior to colorectal surgery significantly reduces postoperative morbidity. In a randomized controlled trial of patients undergoing surgery for gastrointestinal malignancies (colorectal, stomach, and pancreas), Braga et al. found significant clinical benefit in those randomized to receive immunonutrition versus a control enteral formula (66). In this study, patients were separated into four groups: (1) preoperative IMN, (2) preoperative and postoperative IMN, (3) preoperative control isoenergetic/isonitrogenous formula, and (4) no supplementation, demonstrating a significant reduction in infection rates in those who received IMN (12% versus 32%, $p < 0.05$). These results have been replicated with subsequent randomized controlled trials, and most recently, Thornblade et al. published results from Surgical Care Outcomes Assessment Program (SCOAP) in a community setting (67). In this prospective cohort study of 3,357 colorectal surgery patients, the authors reported the applicability of these results outside of a clinical trial. In general, patients receiving IMN had a higher ASA class (III–IV) and were more likely to require an ostomy (18% versus 14%, $p = 0.02$). Although results were not statistically significant, those receiving IMN had lower rates of prolonged length of stay (13.8% versus 17.3%, $p = 0.04$) and decreased rates of serious adverse events (6.8% versus 8.3%, $p = 0.25$). In combination with other components of enhanced recovery pathways, including avoidance of nasogastric tubes, early enteral feeding, carbohydrate loading, and close glucose control, IMN has proven to be a critical component of optimizing surgical outcomes.

IMMUNOSUPPRESSION

Several medications alter the immune response of colorectal surgery patients. In elective surgery, the surgeon may minimize the adverse effects of these medications by careful decision-making regarding surgery timing, technique, and selection for stoma creation.

Steroids are often used to treat IBD in the acute setting and achieve symptomatic control prior to surgical intervention. However, steroids negatively impact all phases of wound healing and are associated with increased rates of venous thromboembolism (68), decreased bone density, and adrenal suppression. Available literature investigating the relationship between steroids and surgical outcomes is largely based on varying definitions of "recent steroid administration" and dosages; however, results are consistent, describing the negative impact of steroids on healing. In a review of NSQIP data, perioperative steroid use was associated with increased rates of superficial SSI (5% versus 2.9%), deep surgical site infections (1.8% versus 0.8%), a two- to threefold higher risk of dehiscence and organ space SSI, and a fourfold increase in mortality in those undergoing abdominal surgery (69). In a study of 250 colorectal patients undergoing left-sided resections with anastomoses, Slieker et al. identified a 7.5% leak rate, with corticosteroid use inferring a sevenfold increased risk of anastomotic leak (70). In particular, the authors emphasized a significantly higher leak rate in those receiving "long-term steroids" (50% leak rate), although duration and dosage of steroids were not described and numbers were small for this subgroup. Similarly, a meta-analysis of 12 studies including 9,565 patients identified an anastomotic leak rate of 6.77% compared to 3.27% in those receiving steroids versus no steroids (71). Despite the variability in defining perioperative steroids regimens, these studies emphasize the increased surgical risk inherent to patients unable to wean or stop long-term or perioperative steroids prior to surgery.

In the last two decades, the treatment of IBD has transformed with the introduction of biologic agents. Biologics are monoclonal antibodies or fusion proteins that bind to strictly defined molecules that play a crucial role in the inflammatory process. Antitumor necrosis factor-alpha (anti-TNF-α) agents, including infliximab and adalimumab, and more recently vedolizumab, are commonly utilized in the treatment of IBD with promising results. Despite these advancements in medical management, up to one-third of patients with Crohn disease will still require surgical resection within 5 years of diagnosis and overall two-thirds of Crohn disease patients will require major abdominal surgery at some point in their lifetime (72,73). Therefore, the impact of biologics on perioperative outcomes remains an area of active interest.

TNF-α increases angiogenesis and collagen production, and therefore it is hypothesized that inhibition of TNF-α delays wound healing, increasing postoperative complications. While this topic has been extensively studied, results

are conflicting. In 2008, Appau et al. demonstrated the negative impact of recent infliximab administration (within 3 months) on ileocolic resection for Crohn disease, reporting a significantly higher rate of postoperative sepsis (20% versus 5.8%, $p = 0.021$), anastomotic leak (10% versus 1.4%, $p = 0.045$), and hospital readmission (20% versus 2.9%, $p = 0.007$) among those receiving infliximab. Syed and colleagues similarly published a single-center study of anti-TNF agents in 325 patients undergoing surgery for Crohn disease, highlighting the negative impact of biologics. In this cohort, 150 patients were exposed to anti-TNF therapy within 8 weeks of abdominal surgery, noting no difference in preoperative nutritional status or corticosteroid or immunomodulator use in the two groups. On multivariate analysis, recent anti-TNF therapy was a predictor for overall infectious (odds ratio [OR] 2.43; 95% CI, 1.18–5.03) and surgical site (OR 1.96; 95% CI, 1.02–3.77) complications (74).

More recently, however, emerging studies have challenged these findings and repeatedly demonstrate the safety of continuing biologics in the perioperative period. In a Danish study of 2,293 patients with Crohn disease who underwent intestinal resection, biologic therapy within 12 weeks of surgery did not predict a higher rate of morbidity and mortality. Furthermore, a subanalysis of this data showed no increased risk of postoperative complications when given within 14 days of surgery (75). Waterman et al. similarly looked at a cohort of 195 IBD patients who were exposed to biologic therapy before surgery and found no difference in postoperative infectious rates when exposure was within 14 days, 15–30 days, or 31–180 days before surgery compared with controls (76). Review of the available data highlights the controversial nature of this topic but increasingly supports the practice of continuing biologic therapy. Perhaps more relevant, however, is the overall impact of combined immunosuppressive agents on wound healing. In the study by Waterman et al., while shorter interval between last dose of biologic therapy and surgery did not increase surgical complications, combination therapy with thiopurine and biologics was associated with higher rates of perioperative morbidity. This point underscores the cumulative effect of immunomodulating agents and cautions one to consider temporary stoma creation in the setting of multimodal immunosuppression.

With continuing advancements in medical immunosuppression regimens, transplant recipients are living longer, and it is not uncommon for the colorectal surgeon to encounter these patients in practice. In the emergent setting, particularly after initial transplantation, these patients are often receiving high-dose immunosuppression, with minimal physiologic reserve, and intestinal anastomoses should be avoided when possible. In the elective setting, however, limited data exist to guide the surgeon in preoperative counseling and decision-making. A study of rodent models undergoing intestinal anastomoses and abdominal wall closure showed that tacrolimus was associated with no difference in wound healing or tensile strength in the early postoperative period (77). In this study, however, wound strength was measured out to 7 days only, while in reality anastomotic complications may present up to 2–3 weeks after the index procedure. Although similar studies of human cohorts are unavailable, Dean and colleagues identified a higher incidence of SSIs and incisional hernias in patients randomized to either sirolimus versus tacrolimus after renal transplantation (47% versus 8%, $p < 0.0001$) (78). Given the lack of evidence to support cessation of these drugs in the perioperative period and the critical role they play in preventing transplant rejection, transitioning from sirolimus to tacrolimus 6 weeks leading up to surgery may be reasonable.

Among colorectal cancer patients, 28,000 patients (20%) will present with metastatic disease at the time of diagnosis. Metastatic colorectal cancer requires a patient-specific, multidisciplinary approach due to the variation in disease burden and distribution. Patients who are asymptomatic at initial presentation often benefit from initial chemotherapy, and those with a favorable response may be appropriate surgical candidates in the future. For those patients who present for elective surgery after neoadjuvant chemotherapy, surgery timing is left to the discretion of the surgeon. The cytotoxic effect of chemotherapy leads to induction of cell death in the setting of colorectal cancer, and theoretically also delays wound and anastomotic healing. Bevacizumab, a humanized monoclonal antibody targeting vascular endothelial growth factor (VEGF) receptor, is considered first-line therapy with FOLFOX in the treatment of metastatic colorectal cancer. Bevacizumab prevents tumor growth by inhibiting neoangiogenesis but can also lead to deleterious effects on healthy tissue in the postoperative setting, delaying wound healing and increasing the risk of infectious, ischemic, and bleeding complications. Bevacizumab has been associated with increased rates of early and late anastomotic complications, including fistula formation up to 5 months after surgery (79–81). With a half-life of 20 (11–50) days, this drug should be held at least 28–40 days prior to elective surgery and postoperatively resumed no earlier than 28 days, and ideally 6 weeks after surgery (82). For those who are unable to afford a drug holiday due to clinical deterioration (obstruction and perforation), stoma creation should be strongly considered, and increased bleeding risk should be anticipated prior to arriving to the operating room.

CHRONIC ANTICOAGULATION AND PERIOPERATIVE MANAGEMENT

With advancements in CVD management, a host of new anticoagulant agents are available. Familiarity with these various medications, including an understanding of their mechanism of action, reversal agent, bioavailability, and half-life, is important to minimize perioperative morbidity. The most common agents will be discussed in this section, acknowledging that we are unable to provide a