General Postoperative Complications

8

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Key Concepts

- Complications following colorectal surgery are not infrequent, making recognition and treatment an important component of the care of postoperative patients.
- Assessment of risk factors (particularly modifiable factors) can help to estimate and reduce the risk of postoperative complications.
- Gastrointestinal complications are the most frequent complications after major abdominal operations and range from minor nausea/vomiting to ileus and bowel obstruction.
- Postoperative bleeding and transfusions are the second most common complication following colorectal surgery, and additional complications such as venous thromboembolism can have major impacts on patients and healthcare systems.
- Infectious complications following colorectal surgery include surgical site infections (SSIs) – which include both incisional and organ space infections, as well as postoperative urinary tract infections and pseudomembranous colitis.
- Pulmonary complications in colorectal surgical patients include pneumonia, aspiration, and postoperative respiratory failure requiring prolonged ventilation.

Introduction

Every operation carries inherent risks for postoperative complications, and the field of colorectal surgery is certainly no different. Colorectal operations account for nearly 25% of all complications in general surgery [1] and have reported complication rates exceeding 35% [2, 3]. A query of data from the 2012 to 2017 American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) Procedure Targeted Colectomy database shows that the most frequent postoperative complication is ileus followed by bleeding and surgical site infections (Table 8.1). Less common complications include myocardial infarctions, pulmonary embolisms, and strokes (Table 8.1). While agencies such as the Centers for Medicare and Medicaid Services (CMS) view complications such as venous thromboembolism as key performance measures, it is increasingly clear that colorectal-specific complications such as ileus and anastomotic leaks have significant impacts on patients, providers, and healthcare systems [4]. It is therefore critical for colorectal surgeons to be able to recognize, understand, and manage a diverse set of complications as they will happen.

Several classification schemes exist to grade complications. One of the most commonly used is the Clavien-Dindo Classification [5, 6]. This classification scheme, refined since 1992, stratifies complications into seven grades (I, II, IIIa, IIIb, IVa, IVb, and V) with increasing severity from grade I (which represents any deviation from the normal postoperative course without a need for major intervention) to grade V (which represents death of a patient). Other classification schemes also exist including a more recently proposed Comprehensive Complication Index [7] by Clavien and Dindo, the Accordion scale [8], and the ACS-NSQIP classification of complications [9]. Despite the heterogeneity in these classification schemes, it is clear that complications matter, as they are associated with increased risks of patient mortality [4, 10], longer lengths of stay [1], more readmissions [4, 11], higher costs [12], and worse long-term oncologic outcomes [13]. Significant responsibility therefore lies with the colorectal surgeon to be experienced not only with performing the index operation(s) but also with managing postoperative complications.

The aims of this chapter will be to provide an overview of common risk factors for postoperative complications and to

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Table 8.1 Common postoperative complications after colorectal surgery using the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) Procedure Targeted for Colectomy (2012–2017)

Complication	Overall frequency (%)	2012	2013	2014	2015	2016	2017
Prolonged postoperative ileus	17.1	15.99	17.07	17.36	17.54	17.28	16.91
Bleeding/transfusion	10.3	12.29	11.67	10.84	10.01	9.13	9.11
Sepsis	5.42	4.77	4.96	5.73	5.51	5.58	5.67
Organ/space SSI	5.07	4.29	4.57	4.99	5.09	5.38	5.63
Superficial incisional SSI	4.96	6.38	5.74	5.4	4.69	4.37	3.99
Septic shock	4.05	3.01	3.98	4.52	4.2	4.16	4.13
On ventilator greater than 48 hours	3.76	4.31	4.15	3.82	3.67	3.6	3.35
Leak	3.38	3.6	3.8	3.41	3.44	3.09	3.23
Pneumonia	3.38	3.15	3.4	3.59	3.46	3.5	3.16
Urinary tract infection	2.53	3.32	2.79	2.71	2.43	2.22	2.12
Unplanned intubation	2.25	2.48	2.45	2.4	2.17	2.11	2.04
DVT requiring therapy	1.47	1.5	1.52	1.44	1.46	1.46	1.45
Wound disruption	1.32	1.51	1.51	1.37	1.32	1.22	1.13
Deep incisional SSI	1.3	1.69	1.76	1.66	1.42	0.86	0.77
C. diff	1.28	–	–	–	0.89	1.55	1.38
Progressive renal insufficiency	0.81	0.78	0.81	0.79	0.8	0.85	0.81
Acute renal failure	0.81	0.86	0.8	0.83	0.81	0.81	0.76
Cardiac arrest requiring CPR	0.79	0.72	0.73	0.82	0.81	0.82	0.79
Myocardial infarction	0.76	0.73	0.64	0.72	0.8	0.81	0.79
Pulmonary embolism	0.67	0.68	0.65	0.71	0.7	0.63	0.68
Stroke/CVA	0.3	0.28	0.32	0.32	0.31	0.27	0.29

Complications listed in order of overall frequency. All numbers expressed as % (frequency)

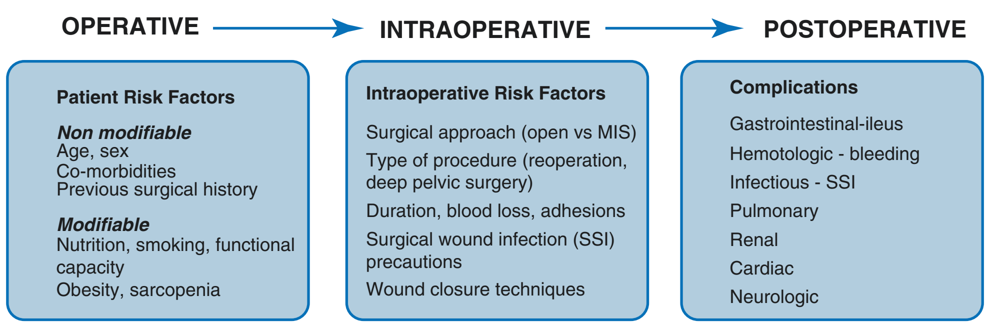

Fig. 8.1 Risk factors for postoperative complications in colorectal surgery

review the management of general complications in colorectal surgery. The discussion will be framed pragmatically in order of frequency of complications using the ACS-NSQIP. Successful acquisition and application of this knowledge will build a foundation for excellence in the care of colorectal surgery patients.

Risk Factors

Successful management of postoperative complications begins with a thorough understanding of the risk factors leading to those complications (Fig. 8.1). Some of these risk factors are non-modifiable (i.e., age and sex/gender), but others are potentially modifiable (i.e., nutrition and smoking). The latter risk factors are prime targets for single-level interventions (i.e., smoking cessation-only) versus more comprehensive interventions (i.e., prehabilitation and enhanced recovery pathways).

Non-modifiable Risk Factors

Age

Older age is a significant risk factor for postoperative complications. The reasons are multifactorial and due to decreased physiologic reserve, worse organ system function(s), cognitive impairment, and increased frailty [14]. Studies have shown that even within the geriatric population, increasing age is a strong independent predictor of mortality and postoperative complications [15, 16]. Among octogenarians [17] and nonagenarians [18], studies have suggested that common operations can be performed safely, but complication rates often exceed 25%. While age is non-modifiable, interventions can target age-associated risk factors such as poor nutrition, sarcopenia, and decreased physiologic reserve. Comprehensive recovery pathways such as Enhanced Recovery Programs (ERPs), for instance, have shown promising early results in improving surgical outcomes and reducing complications for the elderly [19].

Sex

Sex has been shown to be associated with risks of postoperative complications. Recent single-institution studies have associated the male sex with higher risks of complications for laparoscopic and open colorectal operations [15]. Within the ACS-NSQIP database, overall complications were higher for males across many major surgical procedures [20]. Similarly, males have been observed to be at higher risk for anastomotic leaks after colorectal operations [21]. While the underlying mechanism(s) are not clear, complication rates may be higher in males due to sex-based variations in risk prevalence at the patient level (i.e., smoking rates, cardiac disease, etc.) and procedure level (i.e., obesity, narrow pelvis, etc.).

Morbidities

Many patients undergoing colorectal surgery have preexisting comorbidities, and data has consistently shown that comorbidities are linked to the risk of developing a postoperative complication. Patients with American Society of Anesthesiology (ASA) scores of 3–5, for instance, are at significant risk of postoperative complications such as anastomotic leaks [22]. Similarly, patients with a high Charlson Comorbidity Index (CCI) are at increased risk for mortality and morbidities after colorectal operations [23–25]. Additional comorbidities have also been associated with postoperative complications including need for emergency surgery, body weight loss of >10%, use of steroids, congestive heart failure, renal insufficiency, and neurologic deficits [26]. More recent studies have suggested that comorbidities and comorbidity indices should not be considered in isolation. Patients often have "clusters" of comorbidities that in combination drive the risks for complications [27]. While some comorbidities may not be modifiable, a priori knowledge of them can at least provide some knowledge to better educate patients on risks and expected outcomes.

Prior Surgeries and Adhesion Formation

Prior abdominal surgical history is increasingly common, and colorectal surgeons often face reoperative scenarios. For laparoscopic operations, a history of prior abdominal surgery has been shown to be predictive of the need for open conversion, unintentional enterotomies, postoperative ileus, reoperations, and longer operative times [28]. Similarly, the presence of adhesions from prior operations appears to most influence colorectal resections with respect to adhesions-related complications [29]. While past surgical history is considered non-modifiable, experience of the colorectal surgeon is important to help mitigate complications in this circumstance.

Modifiable Risk Factors

Nutrition

Malnutrition is common and may occur in upward of 50% of surgical patients [30]. Several scoring systems such as the Nutrition Risk Screening (NRS) tool [31] and Malnutrition Universal Screening Tool (MUST) have been used effectively to screen patients for malnutrition and help predict outcomes [32]. Early studies since 2002 have demonstrated that preoperative optimization of nutrition benefits malnourished surgical patients [33]. While the optimal content of supplements are still debatable, studies suggests that oral immunonutrition, which often contains arginine and fatty acids, may be one of the key elements [34]. In a large population-based study of 3375 patients in Washington state, significant improvements in length of stay for surgical patients were observed for those on oral immunonutrition with reductions in postoperative complications [35]. Additional evidence suggests that oral supplementation at least 7–10 days prior to an elective operation (and parenteral nutrition only as needed) may improve nutritional status in a malnourished patient to ensure a better surgical outcome [36].

Smoking

Smoking is one of the most significant risk factors for postoperative complications. Multiple studies have associated smoking with complications such as surgical site infections [37], anastomotic leaks [38], and even disease recurrence in inflammatory bowel disease [39]. Smoking risk is modifiable. Randomized trials have shown that smoking abstinence/interventions at 4 weeks before surgery reduces postoperative complications such as wound infections to levels of nonsmokers [40, 41]. In another trial, initiating a preoperative smoking-cessation program 6–8 weeks before the surgical date significantly reduced postoperative complications from 31% to 5% [42]. A recent meta-analysis of 11 randomized controlled trials demonstrated a 44% pooled risk reduction of 30-day postoperative complications with smoking cessation [43]. While the most effective type of smoking-cessation intervention remains unclear, the evidence thus far indicates that preoperative smoking cessation should be a fundamental part of any complication risk-reduction strategy, especially for high-risk specialties such as colorectal surgery [44].

Preoperative Anemia

Anemia is a modifiable risk factor for postoperative complications. In a large ACS-NSQIP study of 23,348 elective open and laparoscopic colorectal operations, preoperative anemia was an independent risk factor for postoperative complications and longer length of stays [45]. More recent studies have also associated anemia with higher risk of postoperative complications [46]. Building evidence suggest that interventions with iron infusions and oral supplementation are effective and mitigate the risks of postoperative complications [47]. In a study on 95 colorectal cancer patients, correction of preoperative anemia with intravenous/oral iron restored hemoglobin levels to normal and corrected anemia patients required no postoperative transfusions (0% compared to 38% transfusion rates for uncorrected, anemic patients) [47]. Societies such as the American Society of Anesthesiologists have established guidelines on the perioperative management of anemia with interventions recommended if time permits [48]. More recently, the Enhanced Recovery After Surgery (ERAS) Society also incorporated anemia management into the most recent 2018 colorectal guidelines [36].

Sarcopenia

Sarcopenia describes the loss of muscle mass and strength that occurs with aging. It may be further accelerated with the presence of chronic diseases and is a result of multiple physiologic mechanisms including declines in growth hormones, nutritional insufficiency, decreased physical activity, and loss of alpha-motor neurons [49]. Retrospective studies in colorectal cancer have associated sarcopenia with an over 82% increased odds of postoperative complications after colorectal surgery [50, 51]. A recent meta-analysis of 29 studies in gastrointestinal cancers showed that sarcopenia was a consistent risk factor for major complications (risk ratio, 1.40) and overall complications (risk ratio, 1.35). Effective interventions to address sarcopenia have yet to be formalized but will undoubtedly work at multiple levels including improving functional capacity and nutritional status.

Obesity

Over a third of adults in the United States are currently obese, with predictions that over half of the US population will be obese by 2030 [52]. Obesity, defined as a body mass index (BMI) of greater than 30 kg/m^2, is increasingly common in the surgical population, and colorectal surgeons often manage these challenging patients. Studies have shown that obesity increases the risk of surgical complications after colorectal surgery [53, 54]. Data using the ACS-NSQIP has suggested that a dose-dependent relationship exists between BMI and complications with increasing obesity classes leading to increasing risks of complications such as surgical site infections [55]. Taken together, these data suggest that obesity is a modifiable risk factor that may be addressable using weight-loss interventions in the preoperative and elective setting [15].

Functional Exercise Capacity

The functional capacity of a patient is measurable and has been linked to surgical outcomes. Similar to athletic training, improving functional exercise capacity is possible. In one of the first studies on prehabilitation, Carli et al. demonstrated that moderate aerobic and resistance exercise significantly improved scores on walking tests [56]. While these improvements were not yet linkable to measurable reductions in postoperative complications, this study formed the basis for further studies that have suggested benefits of prehabilitation programs [44]. A large international, randomized controlled trial by van Rooijen et al. is currently underway to test the effects of a multimodal rehabilitation program on functional capacity (6-minute walk test) in surgical patients [57].

Open Surgical Approach

Open approaches in colorectal surgery have been associated with higher rates of postoperative complications [58]. In contrast, minimally invasive techniques are significantly associated with improved short-term outcomes including decreased surgical site infections, venous thromboembolism events, and pneumonias [58–60]. These associations are complex as hospital/surgical volume and clinical culture also play important roles in determining surgical outcomes [61]. Doing the best operation in the operating room, however, ensures the best start to surgical recovery, and the benefits of minimally invasive techniques are clear – this technique should therefore be utilized whenever possible and currently remains a central tenant of colorectal ERP pathways [36].

Assessing Risk Factors

Risk calculators use population-level data to quantify the risk of complications for individual patients. The POSSUM (Physiological and Operative Severity Score for the enUmeration of Mortality and morbidity) [62] and APACHE (Acute Physiology and Chronic Health Evaluation) [63] scoring systems are two original examples of validated scoring systems that use clinical information to risk stratify. A relatively newer system is the ACS-NSQIP Risk Calculator [64] which was developed to predict risk of postoperative complications, length of stay, mortality, and readmission based on patient- and procedure-level factors (Fig. 8.2). This powerful calculator continues to evolve with the steady accumulation of robust national data annually and identification of new risk factors. In fact, the ACS-NSQIP Risk Calculator was recently updated to include geriatric-specific risk factors to better predict outcomes for the growing geriatric population [65].

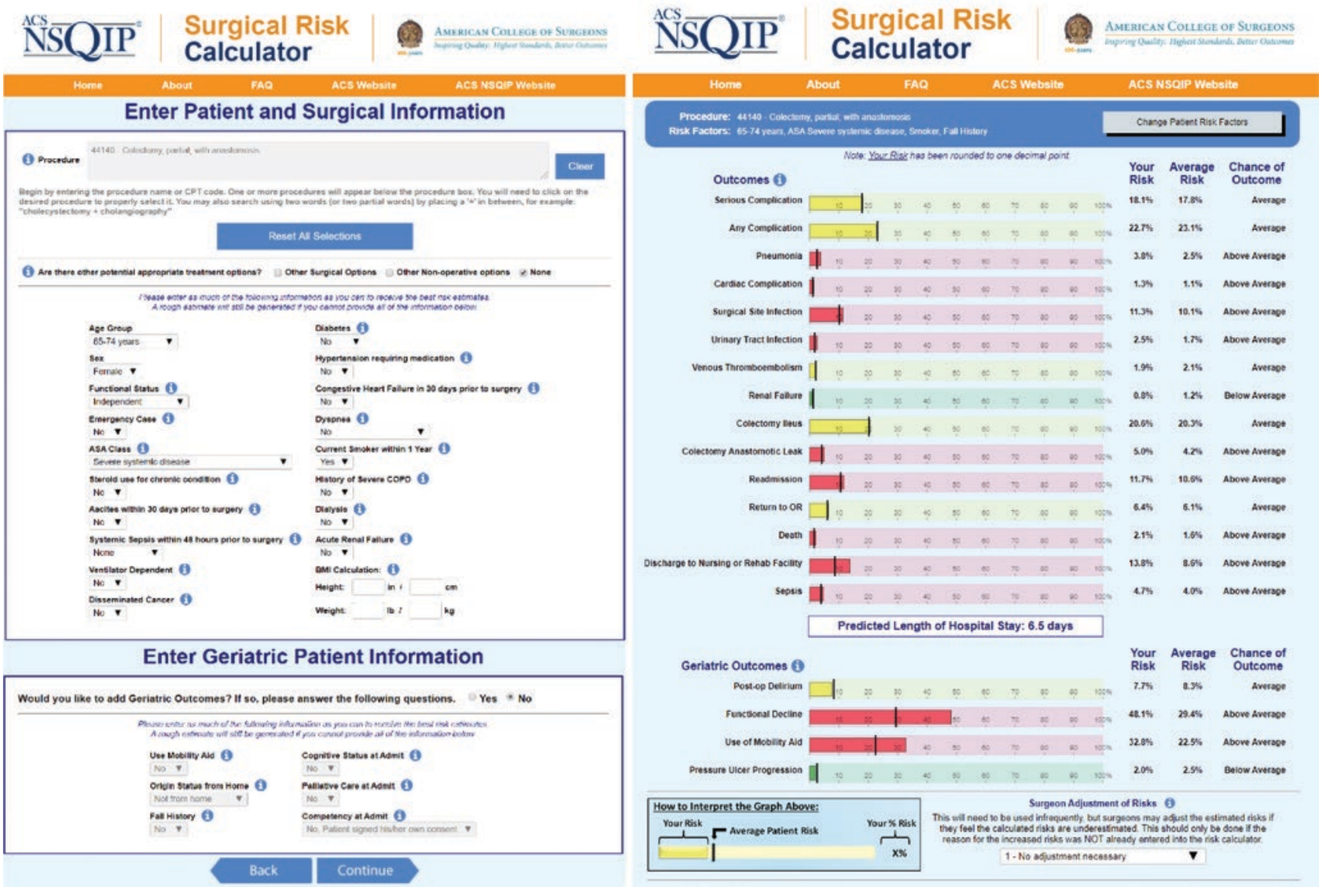

Fig. 8.2 The American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP) Risk Calculator including new geriatric risk factors

Addressing Risk Factors

Once risk is identified, however, the question remains: What can be done? Single-item interventions to address individual risk factors such as malnutrition and smoking have previously been highlighted, but larger gains may be seen with more comprehensive and multilevel interventions. These include programs that are meant to optimize patients before major surgery such as the STRONG program [66] and comprehensive recovery programs such as Enhanced Recovery Programs which aim to mitigate the surgical stress and organ dysfunction associated with major surgery [36]. Prehabilitation is a relatively newer but synergistic program that has gained attention in addressing the risks of complications by specifically targeting risk factor categories (nutrition, smoking, obesity, and physical activity) before surgery [67]. Data is still limited, however, with the most recent study from Carli et al. (2020) showing no demonstrable improvement in reduction of complications as measured by the CCI [68]. Larger multi-institutional trials will aim to establish the effectiveness of such interventions [57].

Postoperative Complications

According to the 2012–2017 ACS-NSQIP database, the most common postoperative complications in colorectal surgery are (1) gastrointestinal complications (ileus), (2) hematologic complications (bleeding), and (3) infectious complications (surgical site infections [SSIs]) (Table 8.1). Other postoperative complications such as cardiac, renal, and pulmonary complications also occur in colorectal surgery but less frequently. This section will review the most common postoperative complications as guided by the ACS-NSQIP database. In addition, a review of other associated but important complications will be presented in an organ system approach.

Gastrointestinal Complications (#1)

Gastrointestinal complications are the most frequent complications after major abdominal operations and range from minor nausea/vomiting to ileus and obstructions. The severity of complications is determined by several risk factors including the type of operation performed, the approach (minimally invasive vs. open), and even blood loss during the case (Fig. 8.1) [69].

Ileus (Functional Bowel Obstruction)

Ileus, which is a functional obstruction of the small bowel, is the single most common complication after colorectal surgery. In the ACS-NSQIP, postoperative ileus rates occur in 12–17% of patients after colorectal surgery (Table 8.1) [4]. This complication drives significant lengths of stay and costs for healthcare systems [4]. The pathophysiology of ileus is unclear but is likely a consequence of disturbances to normal peristalsis governed by the enteric nervous system as a result of anesthetic and surgical manipulation [69]. Disturbances in the large bowel are called pseudo-obstruction or Ogilvie's syndrome [70]. Several factors are known to slow return of bowel function including medications (i.e., opioids), electrolyte abnormalities, inflammatory conditions, pain, and degree of operative manipulation. Patients present with symptoms of nausea, vomiting, bloating, burping, and hiccups in the absence of flatus or bowel movements. Abdominal distension and accompanied tympani are usually observed on physical exam. Abdominal radiographs and computed tomography (CT) scans show dilated loops of bowel but with no transition points or concerns for mechanical obstruction.

Studies have suggested that postoperative ileus can be subdivided into severe ileus and non-severe ileus [71]. In a prospective database from 40 international centers in 5 countries, the rates of severe and non-severe ileus were 9.3% and 6.1%, respectively, even under an Enhanced Recovery Program. Non-severe ileus, or a "primary" ileus, was best treated with nonoperative management including nasogastric tube decompression, bowel rest, intravenous fluids, mobilization, and avoidance of opioids. Severe ileus was very different and driven by intraabdominal complications such as abscesses. As a result, management for severe ileus centers on addressing the underlying insult.

Recommendations for treating functional obstruction such as ileus are to (i) ensure there is no mechanical component to the obstruction, (ii) start with nonoperative management with bowel rest and decompression, and (iii) address underlying causes (electrolyte abnormalities for non-severe ileus and intraabdominal pathology for severe ileus).

Postoperative Small Bowel Obstruction (Mechanical Bowel Obstruction)

Mechanical bowel obstructions in the postoperative setting for the small bowel and colon are most often caused by adhesions. For the small bowel, these obstructions are termed early postoperative small bowel obstructions (ESBO) and occur in upward of 9.5% of abdominal operations [72, 73]. ESBO clinically mimics postoperative ileus, and the differentiating the two can be difficult. Making the correct diagnosis is critical as there is an 8–9% strangulation risk with ESBO [72]. Compared to laparoscopic approaches, open cases are at increased risk for developing this complication. Diagnosis can be made through abdominal radiographs, which may show air-fluid levels in loops of small bowel, and CT scans, which may show a transition point. Strangulation is uncommon from the adhesions themselves, but increasing distension leads to bowel necrosis as mural tension leads to decreased mucosal perfusion. Treatment is usually initially nonoperative with nasogastric decompression, and success rates have been reported as high as 87% [73]. However, if the obstruction does not resolve, then the patient may require operative intervention. The time to wait remains controversial with reports showing safe waiting times from 24 hours to 7 days [74–76], but these decisions are complex and individualized. Reoperations are not without risk as there are increased risks for complications especially for those patients who had an index open operation [72].

Hematologic Complications (#2)

Colorectal operations affect the hematologic system directly and through the coagulation pathway. The 2012–2017 ACS-NSQIP data show that postoperative bleeding and transfusions are the second most common complication following colorectal surgery (Table 8.1). Additional complications such as venous thromboembolism occur less frequently but have major impacts on patients and healthcare systems.

Postoperative Bleeding and Transfusions

Bleeding requiring reoperation is rare after colorectal surgery, but bleeding requiring transfusions may occur in up to 10% of colorectal operations [77]. Risk factors for bleeding include intraoperative factors and medical coagulopathies such as hemophilia A (factor VIII deficiency), hemophilia B (factor IX deficiency), von Willebrand's disease, warfarin therapy, and platelet disorders [78]. One unique intraoperative factor that may lead to significant bleeding in colorectal surgery includes operations in the pelvis. The presacral space is lined by a presacral venous plexus that can be easily disrupted during proctectomy. Trauma to these veins may lead to massive hemorrhage [78].

All postoperative bleeding requires an assessment, resuscitation, and ultimately control. Mild bleeding with no systemic symptoms is often self-limited. Withholding anticoagulants and antiplatelet agents such as nonsteroidal anti-inflammatory drugs (NSAIDs) is first-line and effective step. Severe bleeding with systemic changes such as tachycardia and hypotension requires more aggressive interventions. While radiographic techniques such as CT angiography may be used to identify bleeding sources, delay may be fatal.

In a study of 196 reoperations for bleeding, 77% of take-backs occurred within 24 hours of the index operation with a 28% mortality rate [79]. An expeditious return to the operating room must always be considered if the patient demonstrates signs of exsanguination. Intraoperatively, the source needs to be localized and controlled, clots evacuated, and the peritoneal cavity carefully examined. It is not uncommon to find no active source of bleeding, especially after operations that require significant adhesiolysis and mobilization of retroperitoneal structures. In these situations, a reoperation is still useful as evacuation of the clot may help with achieving final hemostasis.

Presacral bleeding is a challenging situation that all colorectal surgeons must be able to manage. The algorithms are well-established and focus on initial control with packing, resuscitation, and then further action if bleeding persists. These additional actions include suture ligation, sterile thumbtacks, rectus muscle welding, and hemostatic agents [78]. The principles of damage control surgery are also relevant to massive presacral bleeding. In the situation where bleeding control cannot be established, patients should be temporized, packed, and taken back to the ICU to correct acidosis, coagulopathies, and hypothermia. A second operation is usually performed in 24–48 hours with the goal of restoring intestinal continuity, removing packing, and achieving final closure [78]. A related complication is abdominal compartment syndrome, a life-threatening condition that results from massive uncontrolled hemorrhage and/or aggressive resuscitation leading to increased abdominal pressure [80]. When pressures exceed 20 mmHg [78], the compartment must be rapidly decompressed to reestablish flow to the viscera, usually via an abdominal laparotomy. With decompression, symptoms tend to resolve. Complications are high, however, with multi-organ dysfunction and mortality rates approaching 50% [81].

Venous Thromboembolism

Venous thromboembolisms (VTEs) include deep vein thrombosis (DVT) and pulmonary embolism (PE). Colorectal surgery patients are at high risk for developing VTEs because many colorectal diseases such as cancer and inflammatory bowel disease create hypercoagulable states. Among colorectal surgical patients, VTE rates are reported from 1.1% to 2.5% [82]. While not as prevalent as complications such as ileus, VTEs are a common cause of preventable deaths. Many risk factors have been identified including obesity, steroid use, sepsis, reoperations, ASA class 3, and having another postoperative complication [82]. Based on these factors, the American College of Chest Physicians (ACCP) has published important guidelines on risk stratification to guide VTE prophylaxis [83]. These stratifications use validated scoring systems (Caprini Score and the Roger Score) to stratify patients to early ambulation, mechanical prophylaxis, or chemical prophylaxis with low-molecular-weight heparin (LMWH) or low-dose unfractionated heparin (LDUH). Diagnosis for VTEs can be made by (i) ultrasound scanning and D-dimer testing for DVTs and (ii) CT pulmonary angiography and/or D-dimer testing for PEs [84]. Ventilation perfusion scanning (V/Q scan) and V/Q SPECT are reserved for patients with contrast allergies or renal impairment. Prevention of VTEs is more effective than treatment of this complication. Once a VTE is diagnosed, treatment relies upon systemic anticoagulation with chemical agents such as LMWH, coumadin, or newer oral anticoagulants such as dabigatran, apixaban, or edoxaban. In cases where anticoagulation is contraindicated, inferior vena cava (IVC) filters need to be considered to prevent development of a fatal PE.

Infectious Complications (#3)

Infectious-related complications occur frequently after colorectal operations. These complications are usually related to the surgical site. However, infectious complications can occur well away from the surgical bed including urinary tract infections and *Clostridium difficile* infections.

Surgical Site Infection (SSI)

In the United States, an estimated 500,000 cases of surgical site infections (SSIs) are reported each year [85]. As the leading cause of nosocomial infections after surgery, SSIs add over 3.7 million excess hospital days and $10 billion in excess costs per year to the healthcare system [86]. SSIs also add significant morbidity with a 2–11 times higher risk of death for patients who experience an SSI [87]. Importantly, most SSIs are thought to be preventable [88]. Colorectal operations have one of the highest rates of SSIs with reported rates from 15% to over 30% [89].

SSIs are infections in areas where surgery was performed. Classically, SSIs are categorized to (1) superficial incisional (limited to skin/subcutaneous tissues), (2) deep incisional (involves muscle/fascia), and (3) organ space. Risk factors for SSIs include patient factors (i.e., age, nutritional status, diabetes, smoking, obesity, coexistent infection at another site, microorganism colonization, altered immune response, and duration of postoperative stay) and operative factors (i.e., preoperative antiseptic preparation, antimicrobial prophylaxis, duration of operation, operation room venting, use of foreign materials, surgical site, and surgical technique) (Fig. 8.1).

The WHO [90, 91], ACS/SIS [92], and CDC [93] guidelines are major publications that represent the consensus of multidisciplinary experts on SSI prevention strategies. The ACS/SIS, WHO, and CDC reviewed 17, 29, and 42 individual SSI reduction processes, respectively. Interestingly, only a minority of reviewed processes were recommended at the

Table 8.2 Centers for Disease Control and Prevention (CDC) recommendations on prevention of postoperative surgical site infections [93]

Evidence level	#	Specific recommendations	Level of recommendation
Category IA	8	1. Administer IV ABX before skin incision in all C-section procedures 2. In clean and clean-contaminated, do not administer additional IV ABX after incision closed, even in presence of a drain 3. Perioperative glycemic control and target <200 mg/d 4. Maintain perioperative normothermia 5. For patients with normal pulm function under GETA, administer increased FiO2 during surgery and after extubation in immediate postop period 6. Perform intraoperative skin prep with alcohol-based antiseptic agent 7. For prosthetic joint arthroplasty on immunosuppressive therapy, follow #2 8. For prosthetic joint arthroplasty, follow #2	Strong recommendation/ high-quality evidence
Category 1B	4	1. Administer ABX when indicated based on guidelines and time to incision 2. Do not apply antimicrobial agents to incision (topicals) for SSI prevention 3. Advise patients to shower or bathe (full body) with soap (antimicrobial or nonantimicrobial) or an antiseptic agent on at least the night before OR day 4. Do not withhold transfusion of necessary blood products to prevent SSI	Strong recommendation/ accepted practice
Category 2	5	1. Application of autologous platelet-rich plasma is not necessary 2. Consider use of triclosan-coated sutures for SSI prevention 3. Application of a microbial sealant after intraop skin prep is not necessary 4. Use of plastic adhesive drapes with or without antimicrobial properties is not necessary 5. Consider intraop irrigation of deep/subcut tissues with iodophor solution	Weak recommendation
No recommendation	25	1. No RCTs evaluating benefit/harms of weight-adjusted IV ABX dosing and effect 2. … [continues for 24 other parameters]	No recommendations

highest level of evidence. The CDC, for example, noted that only 12 processes had high-quality evidence to support their implementation and 25 processes had no recommendations whatsoever due to the lack of evidence (Table 8.2) [93]. The framework to approaching these guidelines, however, is to consider that there are “core” measures and “supplementary” measures. The former has the most evidence to back their use. The supplementary measures have limited evidence but are in-practice at many institutions.

When comparing the three guidelines, five core themes emerge. These include effective antibiotic prophylaxis, proper preparation of patients and surgeon skin, maintenance of normothermia, glycemic control, and FiO2 of >80% intraoperatively and postoperatively. Antibiotic prophylaxis remains the core of any SSI reduction bundle, as originally championed by SIP/SCIP, and focuses on administering the proper antibiotic within 1–2 hours before incision. Skin preparation focuses on alcohol-based antiseptics combined with agents such as chlorhexidine. Normothermia (≥36 °C) is recommended throughout the operation in addition to perioperative glycemic control, although specific glucose ranges vary across guidelines. Finally, maintaining high FiO2 (>80%) is the most consistent recommendation across all three guidelines. These five elements represent the core components of any effective SSI reduction bundle. Additional elements should be considered supplementary but left to the discretion of the institution to include with consideration of cost-effectiveness. Bowel preparation with a combination of mechanical and oral antibiotics, for example, is recommended by the American Society for Enhanced Recovery (ASER) to reduce the risk of SSIs after colorectal operations [94].

Treatments of SSIs are based on source control. For superficial infections, the treatment typically involves opening the incision, exploring the space, irrigating, and debriding the wound with subsequent regular wound care. Deep incisional and organ space infections may be amenable to percutaneous drainage under image guidance. Those that cannot be adequately drained, in the manner, necessitate a return to the operation room for exploration, washout, drainage, and debridement. Should implanted material be involved (i.e., infected synthetic mesh after a parastomal hernia repair), then it must be removed. Antibiotics alone do not usually address the underlying nidus of infection for deep incisional and organ space infections.

Anastomotic Leaks

Anastomotic leaks are perhaps the most feared complication in colorectal surgery and can occur with any intestinal reconstruction. This complication will be discussed extensively in Chap. 10 and will not be further covered here.

Wound Dehiscence

Wound dehiscence is a partial or complete disruption of any or all layers of the operative wound. Disruption with extrusion of abdominal viscera is evisceration, which requires immediate operation. Long-term effect of wound disruptions manifest as incisional hernias. Wound dehiscence is rare and occurs in 1–3% of colorectal surgeries [95]. Systemic and local factors contribute to the development of this complication. Systemic factors include any comorbid conditions that lead to poor wound healing (i.e., diabetes mellitus, uremia, impaired immune function, steroid use, poor nutritional status, cancer, obesity, and smoking). Local factors include inadequate closure, increased intra-abdominal pressure, and poor wound healing. In a Swedish population-based study of 30,050 patients in 2007–2013, wound dehiscence requiring reoperation occurred in 2.9% of patients after colorectal cancer surgery. While these complications were rare, adjusted mortality risk was significantly increased by 26% [95].

Proper wound closure is one of the most important and modifiable factors to prevent wound dehiscence. Key principles include a clean initial incision, appropriate tissue handling/suture material, and adequate spacing of the sutures. The STITCH trial was a multicenter randomized controlled trial that compared small bites (5 mm of fascia every 5 mm of advancement) to large bites (1 cm of fascia every 1 cm of advancement) with respect to the development of incisional hernia [96]. The small bite technique was more effective than the large bite technique with lower rates of incisional hernia (13% vs. 21%). Placement of retention stitches should be considered in high-tension wounds or patients with increased risk factors. In a randomized controlled trial of 300 high-risk surgical patients randomized to closure with retention sutures versus standard continuous fascia closure-only, wound dehiscence and evisceration occurred significantly less in the retention group (4% vs. 13.3% and 0.7% vs. 2.7%, respectively) [97].

Other Infectious Complications

Urinary tract infections (UTIs) are the most frequently acquired nosocomial infection. The incidence of postoperative UTI after colorectal operations approaches 4% [98]. Risk factors include preexisting contamination of the urinary tract, urinary retention, and instrumentation such as indwelling urinary catheters. In a large retrospective study of the 2005–2012 ACS-NSQIP database, patients with postoperative UTIs had significantly longer length of stays (+5 days), higher reoperation rates (11.9% vs. 5.1%), higher 30-day mortality (3.3% vs. 1.7%), and more concurrent complications such as sepsis [98]. Diagnosis of UTI is made by examination of the urine with confirmation by cultures. Prevention involves treating urinary tract contamination before surgery, prevention or prompt treatment of urinary retention, and careful instrumentation when needed. Treatment includes adequate hydration, proper drainage of the bladder, and urine-specific antibiotics.

Clostridium difficile Colitis

Clostridium difficile (*C. diff*) is one of the most common nosocomial pathogens and the cause of 10–20% of antibiotic-associated colitis and diarrhea [99]. Postoperative *C. diff* infections occur at an incidence of 0.2–8.4% after major surgeries [99]. While infrequent, the overall incidence of *C. diff* infection is increasing in the United States [100] with significant morbidity for affected patients. Risk factors include antibiotic use, PPI use, low albumin, and prior hospitalization [99]. The history, physical exam, and laboratory testing should all be used to aid in the workup and diagnosis of *C. diff* colitis. Stool testing should follow protocols to ensure the highest specificity and sensitivity while remaining practical and time-sensitive. Depending on patient presentation, radiographic and endoscopic testing can complement the workup to determine the most appropriate and effective treatment plan. Treatment options range from oral antibiotic therapy (oral vancomycin) to consideration of fecal transplantation to urgent/emergent surgery.

Pulmonary Complications (#4)

Pulmonary complications may occur after any major surgery. In colorectal surgery, pulmonary complications include postoperative respiratory failure requiring prolonged ventilation, pneumonia, and aspiration. Each of these complications drives longer hospitalizations and often leads to further serious complications.

Postoperative Respiratory Failure

Postoperative respiratory failure is defined as postoperative ventilation for >48 hours or patient reintubation. In the 2012–2017 ACS-NSQIP database, prolonged ventilation occurred in 3.3–4.3% of colorectal patients with reintubation rates around 2.3% (Table 8.1). Risk factors include poor preoperative lung function, age, concomitant comorbidities (i.e., obstructive sleep apnea, pulmonary hypertension, and cardiovascular disease), smoking, and aspiration. Preventative measures include fast-track extubation, effective pain therapy, breathing training, physiotherapy, noninvasive ventilation, use of bronchodilators, and appropriate volume resuscitation. Studies using ERPs have demonstrated positive results in reducing the occurrence of these pulmonary complications by standardizing best practices for pulmonary function [101]. In a retrospective analysis of 1298 patients under an ERP, minimally invasive approaches and >70% compliance with ERP processes prevented pulmonary complications. Patients who did have pulmonary complications had a significantly longer hospital length of stay (+15 days) [101]. Treatment of respiratory failure is primarily supportive and includes early tracheostomy (to decrease dead space), protective ventilation, lowered peak pressures (<30 mmHg), increased positive end-expiratory pressure (PEEP 10–20 mmH$_2$O), early patient mobilization, and bronchoscopy as needed. Critical cases may lead to use of extracorporeal membrane oxygenation (ECMO).

Pneumonia

Pneumonia is the most common pulmonary complication among patients who die after surgery. Mortality rates for postoperative pneumonia vary from 20% to 40% and include both hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) [102, 103]. In colorectal surgery, the incidence of postoperative pneumonia has been reported from 1% to 4% [104]. The etiology of postoperative pneumonia is multifactorial. Atelectasis, aspiration, and secretions are important predisposing factors. Patients may also be exposed to nosocomial infections such as *Pseudomonas aeruginosa* and *Klebsiella* in the ICUs [105]. Clinical findings suggestive of postoperative pneumonia include fever, tachypnea, increased secretions, and physical exam suggestive of pulmonary consolidation. Chest X-rays and CT scans of the chest may show patchy opacification and/or localized consolidation. Several strategies may be used to decrease the risk of postoperative pneumonia. Respiratory exercises, deep breathing, coughing, and mobilization may help prevent atelectasis, which is a precursor of pneumonia. It is important to stress that control of postoperative pain is important for these actions to occur – one of the many focuses of ERPs [36]. Subglottic secretion suctioning on ventilated patients has also been shown to reduce ventilator-associated pneumonias [106]. The benefits of minimally invasive approaches may also extend to prevention of pneumonia [107] and to the elderly [108]. Treatment is supportive and based on aggressive ventilatory support and parenteral antibiotics.

Pulmonary Aspiration

Postoperative aspiration occurs in 1–2% of surgical cases [109] with mortality rates exceeding 30% [110]. Normal protective reflexes are often compromised in the postanesthetic state, with depressed mental status and the presence of a foreign body (i.e., nasogastric or endotracheal tubes). Additional risk factors include older age, pulmonary disease, need for intraoperative blood transfusions, dementia, and malignancy [110]. Aspiration of orogastric contents leads to severe pneumonia and pulmonary compromise with resultant prolonged hospital lengths of stays, costs, and death [109]. Prevention of aspiration includes preoperative fasting, proper positioning, careful intubation, and use of histamine-2 blockers [111]. Effective aspiration prevention protocols have been further developed that focus on bedside swallowing evaluations and stepwise advancement of oral intake [112]. Treatment of aspiration involves reestablishing patency of the airway and preventing further damage to the lung. Endotracheal bronchoscopy may be required to remove solid matter. Fluid resuscitation and antibiotics should be started concomitantly with aggressive management to prevent death and development of other complications.

Renal Complications (#5)

Renal complications affect the urinary tract and include acute kidney injury and postoperative urinary retention. While often reversible, these complications increase the risk of having long-term damage such as chronic kidney injury requiring dialysis.

Acute Kidney Injury

Acute kidney injury (AKI) describes a decrease in renal function over a course of hours to days that may range from a minor decrease in glomerular filtration to complete renal failure. The ACS-NSQIP defines AKI as a change in serum creatinine >2 mg/dl or a need for acute renal replacement therapy [64]. Postoperative AKI is a common complication in surgery and may affect up to 40% of the surgical population [113] and 14% of the colorectal population [114]. Development of postoperative AKI is associated with significant risks of both short- and long-term mortality, chronic kidney disease, and hemodialysis [113]. Risk factors include hypovolemia, bleeding, nephrotoxic agents, and cardiovascular failure. Preventative measures include avoidance of hypoperfusion and careful administration of nephrotoxic drugs including contrast agents. Treatment is supportive and based on volume replacement, preventing further renal damage and alleviating any obstructive pathologies.

Postoperative Urinary Retention

The inability to void postoperatively is common after anorectal and pelvic operations. Postoperative urinary retention (POUR) rates may occur in up to 25% of colorectal patients [115]. Even under modern ERP pathways, POURs still occur. In a study of 513 ERP patients in Switzerland, POUR occurred in 14% of patients [116]. These patients had worse surgical recovery including slower mobilization rates, more pain, and more UTIs. In that study, independent risk factors for POUR include male gender and thoracic epidural analgesia [116]. The treatment of POUR requires catheterization of the bladder and subsequent removal based on voiding ability. Efforts have recently been made in preventing POUR by administrating tamsulosin in the days before and after surgery. In one study, a threefold decrease in POUR rates was observed (25–6.7%) after administration of tamsulosin 3 days before surgery and 3 days after surgery [115].

Cardiac Complications (#6)

Cardiac complications following colorectal surgery are rare but life-threatening. Patients with risk factors of cardiac disease need to undergo appropriate cardiovascular testing and intervention prior to surgical intervention. Important guidelines from the American College of Cardiology (ACC) and

American Heart Association (AHA), supported by the ACS, exist that provide evidence-based recommendations for risk stratification and optimization of patients before major surgery including colorectal surgeries [117].

Myocardial Infarction

Approximately 1.5% of all patients undergoing a colorectal operation in the United States experience a postoperative myocardial infarction (MI) with mortality rates exceeding 28.5% [118]. Nearly 16% of all surgical patients, however, may experience a myocardial injury, and even these mortality rates are high (8.9%) [119]. Risk factors for postoperative MI include history of congestive heart failure, chronic renal disease, age >70 years old, peripheral vascular disorders, cancer, valvular disease, and hypertension [118]. Risk stratification and perioperative optimization are critical for colorectal patients as avoidance of this complication is the best strategy. The most cited and comprehensive guideline for stratification and optimization is the 2014 ACC/AHA Guideline on Perioperative Cardiovascular Evaluation and Management of Patients Undergoing Noncardiac Surgery [117]. These guidelines provide stepwise approaches to preoperative cardiac assessments including (i) initial clinical risk stratification of patients to low (<1% risk of major adverse cardiac event, MACE) and elevated (>1% MACE) risk categories, (ii) functional capacity assessment by metabolic equivalent of task (MET) for elevated risk patients (<4 MET = poor, 5–10 MET = moderate/good, and ≥11 MET = excellent), (iii) pharmacological stress testing for elevated risk patients with poor (<4 MET) or unknown functional capacity, and (iv) coronary revascularization for those with abnormal stress testing [117]. Treatment for MIs and other MACEs is supportive, and immediate consultations with cardiology (and potentially cardiac surgery) should be made to best individualize care and rescue these patients.

Dysrhythmias

Dysrhythmias such as atrial fibrillation occur after colorectal surgery. In a study of 571 colorectal patients, the incidence of postoperative atrial fibrillation (POAF) was 6.6% within 30 days of surgery [120]. This complication was closely associated with development of other complications including pneumonia, abdominal fluid collections, and sepsis. Patients with POAF were at higher risk for in-hospital mortality (9.1% vs. 2.6%) and 1-year mortality (33.3% vs. 8.8%) [120]. Preventative strategies to POAF include pharmacologic therapies (e.g., continuing beta-blockers), fluid optimization, and minimizing risk of other complications [121]. Treatment for POAF necessitates the involvement of cardiologists as there are both short- and long-term management strategies using rate-control medications (beta-blockers) and cardioversion [122].

Neurological Complications (#7)

Neurological complications in colorectal surgery include those complications that are captured by ACS-NSQIP (cerebrovascular accidents such as strokes) and those that are not but are equally important to identify (sexual dysfunction, delirium, etc.). While these complications can be devastating, significant improvements have been made in preventing them and managing them.

Perioperative Cerebrovascular Accidents

Perioperative strokes occur infrequently (0.3% rate from 2012 to 2017 ACS-NSQIP database) (Table 8.1) but are associated with significant perioperative morbidity and mortality. Most are thromboembolic events and occur within the initial 72 hours postoperative period. Risk factors include the type of surgery performed, intraoperative hypotension, history of previous stroke, cardiac issues (atrial fibrillation, valvular heart disease, mechanical valves, etc.), hypertension, peripheral vascular disease, age, neoplastic disease, and smoking [123]. Cerebrovascular events usually present with an acute neurologic change (i.e., weakness, facial droop, slurred speech). Workup involves getting an initial non-contrasted CT of the head to differentiate whether the stroke is ischemic or hemorrhagic. Treatment is dependent on the type of stroke, and neurology consultations are recommended for individualized management.

Sexual Dysfunction

Colorectal operations carry a risk of postoperative sexual dysfunction, typically due to injury to the nerves during pelvic dissection [124]. The pudendal nerves are not typically damaged during proctectomy; however, the nerves which are important in coordinating erection (nervi erigentes) and ejaculation (hypogastric nerves) may be affected. The hypogastric nerves include pre- and postganglionic sympathetic fibers from vertebral levels of T10-L2 and descend in the retroperitoneal space at the level of the sacral promontory. Injury to these nerves can occur during the posterior dissection of a total mesorectal excision or during transection of the inferior mesenteric artery and can result in ejaculatory dysfunction. The nervi erigentes (or pelvic splanchnic nerves) arise from the anterior rami of S2-S4 and enter the sacral plexus along the anterolateral wall of the rectum. Erectile dysfunction may occur due to avulsion from excessive traction of the rectum during proctectomy or by direct injury of the nerves during dissection near the seminal vesicles and prostate.

The incidence of postoperative sexual dysfunction in males varies widely in the medical literature (from 5% to 90%), and a significant number of patients may suffer from preoperative dysfunction [124]. In a prospective study of 169 patients who underwent proctectomy for rectal cancer, Adam et al. [125] found that 71% of males reported erectile dysfunction after surgery (vs. 24% preoperative) and 78% reported ejaculatory dysfunction (vs. 32%) ($p < 0.001$). Stage T3 or T4 tumors and low rectal tumors were independent risk factors of worse sexual function. Similarly, Dulskas and Samalavicius reported postoperative erectile dysfunction in 63.9% of patients; however, the incidence of preoperative dysfunction was 41.7% [126]. Sexual dysfunction may be higher in patients who undergo abdominoperineal resection than those who undergo low anterior resection.

Psychological evaluation and support of the patient and his/her partner are important and can improve the response to pharmacologic therapy [127]. Among the medications available, the efficacy of sildenafil was demonstrated in a study where 32 patients who had undergone proctectomy were randomized to treatment or placebo [128]. Erectile function improved in 80% of patients treated with sildenafil compared to only 17% of patients treated with placebo.

Determining significant changes in sexual function in older women following proctectomy can be more difficult, as a high percentage of women report baseline preoperative genitourinary dysfunction [4]. Younger female patients who undergo pelvic surgery for benign disease may be at risk of fertility problems, likely due to extensive dissection leading to intra-abdominal and pelvic adhesions. Waljee et al. reported a threefold increase in the risk of infertility following total proctocolectomy in patients with ulcerative colitis (48% vs. 15%) [129]. In a more recent meta-analysis, Rajaratnam et al. showed that the risk of infertility is almost four times higher following IPAA [130]. While it would seem that a laparoscopy would reduce adhesion formation and therefore reduce the risk of infertility, a recent retrospective comparison of 161 patients did not demonstrate a difference in infertility rates between open and minimally invasive approaches [131].

Postoperative Delirium

Postoperative delirium (POD) is a form of delirium that occurs after a surgical procedure and may occur at rates as high as 87% [132]. Risk factors include reduced cognitive reserve from preexisting comorbidities (i.e., dementia and age), sensory impairment, dehydration, substance abuse, withdrawal of certain types of medications (anticholinergics, benzodiazepines, etc.), sleep-wake cycle disturbances, and environmental change (i.e., prolonged hospitalization or ICU stay) [133]. Patients with delirium are at increased risk for adverse outcomes including higher mortality, longer hospital stays, and discharge to nursing facility [134]. Preventative measures include frequent and deliberate orientation of patient to place/time, early postoperative mobilization, and consistent use of home devices while hospitalized (i.e., hearing aids and glasses). In the ICU, sedative medication should be titrated between patient comfort and oversedation. Treatment is supportive and includes supervision/reorientation, removal of inciting agents, and pharmacologic therapies.

Conclusion

Postoperative complications are an inherent part of colorectal surgery. All lead to increased risks of mortality, prolonged hospital length of stays, readmissions, and other adverse outcomes. The most common complications in colorectal surgery include ileus, bleeding, and surgical site infections. It is critical for colorectal surgeons to be aware of the many risk factors for these complications and to optimize patients preoperatively. When complications occur, surgeons need to recognize them early, respond in an expedient manner, and administer the appropriate treatment to rescue the patient and achieve the best possible outcome.

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