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Postoperative Complications

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Key Concepts

- Thorough preoperative evaluation including assessment of social situation, cognitive status, and comorbidities contribute to safe postoperative recovery.
- Laparoscopic approach to colorectal surgery is associated with a decreased risk for postoperative complications.
- Risk for mortality after major postoperative complications is a reflection of surgeon as well as the system in which the surgeon operates.
- Meticulous operative technique with particular attention to hemostasis will lead to improved postoperative outcomes.
- Postoperative management with an enhanced recovery after surgery protocol leads to decreased postoperative complications.
- Bowel preparation with oral antibiotics correlates with a decreased risk of superficial surgical site infection.

Introduction

Postoperative complications are common in colorectal surgery with an incidence as high as 40 % depending upon the study. Many studies have been reported which characterize the complications and their frequency. The overarching goal of this chapter is to highlight some of this literature in an attempt to give the reader a broad overview of some of the issues surrounding postoperative complications.

Preoperative Considerations and Prediction of Postoperative Complications

Given the frequency of postoperative complications and their implications on quality of life, much current work focuses on prevention of complications. To that end, many authors have used the database that has come out of the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) to characterize postoperative complications [1–6]. Perhaps one of the most significant developments is that of the ACS NSQIP surgical risk calculator [7, 8]. This tool uses procedure-specific information to provide an accurate prediction both of risk for various complications as well as hospital length of stay. Importantly, the ACS NSQIP calculator provides risk stratification that allows the patient to see their risk in the context of other more average-risk patients. Figure. 8-1a, b is an example of a report obtained from the ACS NSQIP risk calculator. These types of tools allow surgeons to not only anticipate various complications but to guide patient counseling on expected outcomes. This type of informed consent allows surgeons to consider the outcomes that are most important to patients so they can make decisions that align with their goals of life [9, 10].

While this risk calculator seems to accurately predict postoperative complications [8], risk prediction is dependent upon the accuracy of the data entered into the model. Furthermore, factors exist that impact the outcomes that cannot be measured by any specific model. For example, Dr. Senagore's group investigated the accuracy of the ACS NSQIP risk calculator in predicting outcomes in a high-volume minimally invasive colorectal surgery practice [11]. The authors of this study found that the risk calculator generally overestimated the rate of complications [11]. The authors proposed that the discrepancy in the observed to expected rate of complications was related to the inability of the calculator to account for surgeon-specific experience, volume, and prior outcomes. However, the authors did not report how well the results of the calculator correlated with the actual patient outcomes on a per-patient basis, which is a major limitation to their conclusions. Nonetheless, it is clear that any prediction calculator developed will always be able to be improved with more accurate data input.

Patient comorbidity clearly impacts risk for postoperative complications [1]. The NSQIP risk calculator, as well

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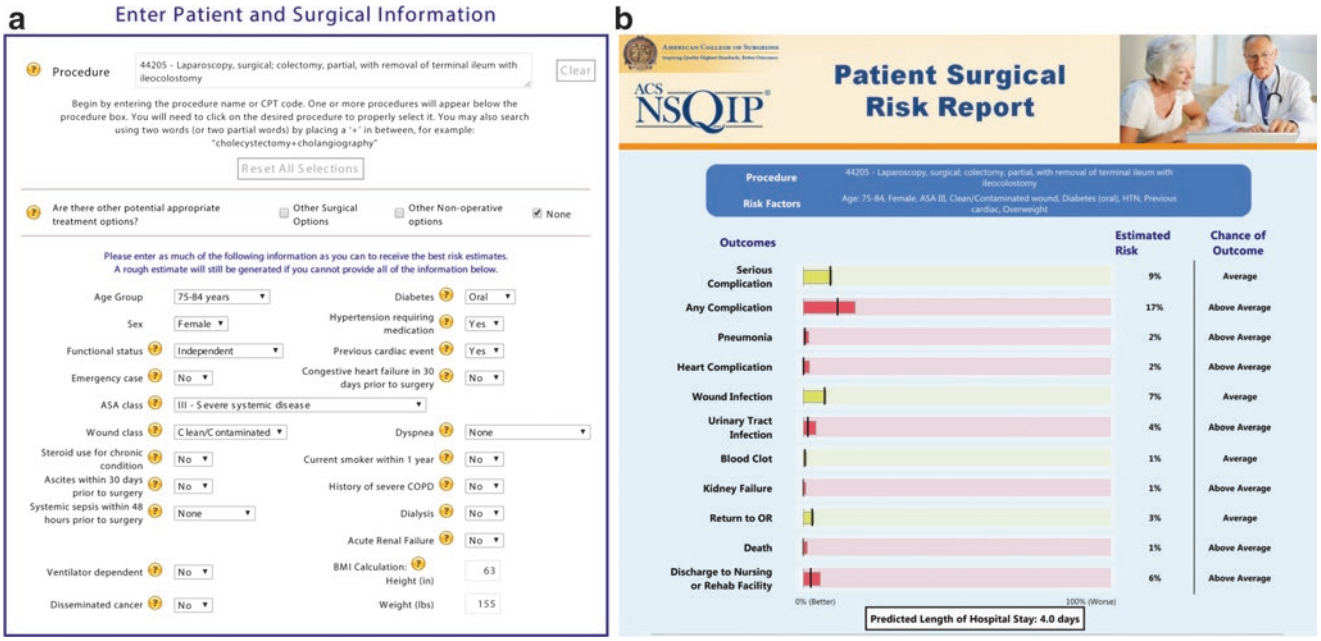

FIGURE 8-1. A sample of the American College of Surgeons risk calculator is shown. The calculator was found at http://riskcalculator.facs.org/ and details of a made-up patient were inserted according to the instructions. (**a**) In this example, a 77-year-old female patient will undergo a laparoscopic right hemicolectomy. Her made-up comorbidities were inserted and the risk calculator was run. (**b**) Results of the risk calculation were obtained and shown here. This sample patient was found to be of average risk for serious complication and slightly higher than average risk for any complication. Risks for specific complications are shown. © American College of Surgeons, used with permission.

as many other investigators, has clearly shown the impact of these comorbidities on risk for postoperative complications. However, as patients with surgical problems age, surgeons must be able to address issues that are specific to the older adult population. In particular, it is important to begin to understand how frailty, cognitive impairment, and social support impact patient outcomes. These variables are largely neglected by any current predictive nomogram, but it is clear that these factors contribute to postoperative outcomes. For example, cognitive impairment has been shown to correlate with discharge to a higher level of care in the older adult population [12]. In this study, 41 % of patients with a score ≤14 on the mini-mental status examination (MMSE) were discharged to a higher-level care facility compared to only 11 % of patients who scored >14 (OR 4.76, CI 1.72–13.17, $P=0.003$) [12]. These findings indicate that preoperative cognitive impairment is an important predictor of discharge destination. Others have also found that preoperative cognitive impairment correlated with a higher risk for postoperative complications (42 % rate of complications in the impaired group compared to 24 % in the intact group, $P=0.011$) [13]. Cognitive impairment also correlated with longer length of stay and higher 6-month mortality. Taken together, the data indicate that cognitive impairment should be considered an important predictor of outcome when dealing with the older adult population.

Another commonly forgotten consideration in the high-risk older adult population is frailty. Frailty is a syndrome characterized by age-related declines in functional reserves across an array of physiologic systems. The syndrome is highly prevalent in older adults and confers a high risk for falls, disability, hospitalization, and institutionalization. Despite the prevalence of this syndrome in older adults and the wide recognition of the importance of frailty on postoperative outcomes, it has not been well defined in the literature until recently. Many different strategies have been used to measure frailty [14]. Perhaps the best measurement is termed the frailty phenotype that is characterized by unintentional weight loss, decreased energy, and decrease in activity and strength [15]. It is clear that frailty directly impacts postoperative outcomes in the older adult population [16, 17]. In fact, given all of the issues associated with surgical care of the older adult patient, the American College of Surgeons assembled a task force of experts to put together a best practice guideline for the optimal preoperative assessment of this group of patients [18].

Finally, as a patient is assessed in clinic for an operation, another important factor likely to impact the recovery course is the social structure of the patient. Many authors have investigated how social structure impacts postoperative recovery and results have been mixed [19]. In general, it is thought that social structure contributes to postoperative recovery either in alleviating anxiety, pain, or response to

pain [20, 21]. One group from Michigan recently examined the concept of social connectedness as it relates to postoperative recovery [22]. They found that patients with more social connectedness, as measured by number of friends and family as well as by interaction within the network, experienced less subjective pain and less perceived unpleasantness from the pain as compared to patients who had less social connectedness [22]. While it is clear that a patient's social structure is related to their perception of the recovery, it is not understood if connectedness contributes to recovery after suffering a major complication or if the concept of connectedness contributes to a patient's underlying risk for suffering a postoperative complication. It is likely that social connectedness does contribute to risk, as patients who are alone may have poor overall health and malnutrition [23].

As we consider the future, we must begin to consider how to properly counsel patients prior to surgical intervention. Quality measures, including outcomes related to safety, effectiveness, and patient centeredness, are already included in many facets of clinical practice such as credentialing and reimbursement. Therefore, it is imperative that all surgeons embrace these measures, become more comfortable with the details, and strive to improve outcomes. Risk stratification systems such as the ACS NSQIP risk calculator will be important in preoperative assessment. How these assessments will be used to change management and outcomes remains to be determined. Future work will focus on enhancing the scoring systems as well as understanding how a surgeon can modify the approach to improve surgical outcomes.

Intraoperative Factors that Contribute to Postoperative Outcomes

Operative Approach and Postoperative Impact

Laparoscopy for colon surgery was first reported in a small case series in the early 1990s [24]. Shortly after these reports, Dr. Wexner and his group published results from their earliest prospective studies, which found no difference in outcomes between open and laparoscopic-assisted colectomy [25, 26]. These studies began the debate on the role of laparoscopy in the treatment of colorectal diseases. Multiple subsequent publications have highlighted the benefit of a laparoscopic approach to colorectal surgery. Nonetheless, it is interesting to note that in many circles this debate continues in spite of the multiple published studies highlighting the benefits of a laparoscopic approach to colorectal surgery. However, it is important to consider those endpoints that are affected by surgical approach in order to fully appreciate the benefit of laparoscopy in improving outcomes.

Postoperative bowel obstruction is a common complication of many abdominal and pelvic surgical procedures. Given the unpredictable timing and potentially quite delayed presentation of postoperative bowel obstruction, it is difficult to know the exact incidence of this complication. A landmark paper published in 1999 by Beck et al. used the Health Care Financing Administration dataset from 1993 to address this question. They found that between 12.4 and 17 % of Medicare beneficiaries undergoing either pelvic or abdominal operations suffered a bowel obstruction sometime within 2 years of the primary operation [27]. Importantly, this study found the incidence of bowel obstruction to be quite a bit higher than previous reports. Since this paper, others have found the incidence of bowel obstruction due to adhesive disease to be less than 3 % and to be dependent upon the cavity in which the operation was performed [28]. For example, in one study, an operation on the lower GI tract carried a higher risk for bowel obstruction than did an operation on the abdominal wall only (3.8 % versus 0.5 %) [28]. The evidence regarding the impact of laparoscopy on the development of postoperative bowel obstruction is somewhat mixed [28, 29]. A retrospective study of nearly 300 patients undergoing restorative proctocolectomy at a single institution found no difference in incidence of postoperative small bowel obstruction between open and laparoscopic approaches [30]. In summary, the use of laparoscopy may decrease adhesion formation, which likely will result in lower rates of adhesive postoperative bowel obstruction.

The impact of laparoscopy on other complications and outcomes is more clear. The prospective randomized controlled trial reported by the Clinical Outcomes of Surgical Therapy Study Group found that perioperative recovery was faster in subjects randomized to laparoscopy compared to those undergoing open procedures, as reflected by a shorter hospital length of stay [31]. Rates of intraoperative complications, 30-day mortality, complications at discharge and at 60 days, hospital readmission, and reoperation were similar between groups [31]. Similarly, results from the MRC CLASICC trial demonstrated shorter length of stay for patients treated with a laparoscopic approach, with no difference in 30-day or 3-month complications [32]. While these randomized controlled trials failed to show differences in some short-term outcomes between operative approaches, it should be noted that they were not designed to detect these differences. Furthermore, randomized controlled trials are inherently biased and nonrepresentative of the daily practice of medicine and surgery, which highlights the importance of observational and comparative effectiveness studies [33].

A review of the literature reveals several comparative effectiveness studies looking at the issue of laparoscopic versus open approach to colon surgery. In general, all have found that minimally invasive techniques are correlated with improved short-term outcomes. Specifically, these studies report at least a 50 % reduction in superficial surgical site infections, a 50 % reduction in deep wound infection, and a significant reduction in postoperative length of stay in patients who have a laparoscopic operation [5, 34–42]. However, these studies have generally reported similar mortality associated with the two approaches, suggesting that

while surgical approach may decrease some types of postoperative complications, other outcomes such as mortality are more complex and multifactorial. In fact, when examining the so-called "failure to rescue" phenomenon first published by Silber in 1992 [43], it is clear that the surgeon, surgical volume, and the system in which the surgeon operates contribute to the rate of postoperative mortality following major complications [44–46].

In summary, operative approach clearly relates to the development of postoperative complications. The exact mechanism of protection provided by the minimally invasive approach is unknown and is not reflected in every outcome. Therefore, future research should address the complication phenotype, and surgeons should strive to reduce variability in operative approach.

Luminal Organ Injuries and Postoperative Impact

In 2003, the Agency for Healthcare Research and Quality (AHRQ) proposed a set of patient safety indicators (PSIs) intended to reflect the quality of care delivered in hospitals. Several PSIs are included in the current CMS pay for performance plan, directly affecting reimbursement. These PSIs are presumed to be preventable by provider or system changes and include iatrogenic events such as accidental puncture or laceration (APL) during a procedure. Accidental puncture or laceration is defined as an accidental perforation of a blood vessel, nerve, or organ occurring during a procedure [47]. When applying this definition to over two million Veterans Health Administration admissions, 7023 were flagged for APL. These included serosal tears, enterotomy, and injury to the ureter, bladder, spleen, and blood vessels. Of true APLs, 27 % were minor injuries such as small serosal tears with no clinically significant impact [48]. The clinical significance of serosal tears is also found to be minimal in other large-volume studies [49]. In fact, further evidence from the Cleveland Clinic group found that accidental puncture laceration was more correlated with complexity of the operation and largely had no impact on postoperative recovery [49]. Since the rate of APL is publicly available and used in pay for performance models, it is important that we fully understand the limitations of this PSI. These data suggest that the utility of APL is limited and better measures of safety are necessary if we are to compare organizations in a fair and non-biased fashion.

Vascular Injury and Failure of Hemostatic Devices

Blood loss has been shown in many studies to correlate with outcomes across various different types of operations [50–52]. Using the NSQIP PUF database, Greenblatt et al. found intraoperative blood transfusion to be significantly associated with postoperative complications in patients undergoing surgery for rectal cancer [53]. These results are consistent with those found in the single-institution study published by Gu and others examining outcomes in patients undergoing ileal pouch-anal anastomosis [50]. Halabi et al. demonstrated a dose-dependent effect of blood transfusion, with worse outcomes in patients receiving more than 3 or more units of blood compared to those receiving only 1–2 units of blood [54]. All of these data together indicate that careful attention to hemostasis is not only consistent with good operative technique but also contributes to decreased postoperative morbidity.

The exact incidence of major vascular injury during colorectal surgery is unclear. However, examination of the surgical literature indicates that major vascular injury is relatively rare. For example, in a series of 404 patients undergoing retroperitoneal laparoscopic nephrectomy, Meraney and colleagues reported seven patients who had major vascular injuries. Conversion to open or repair of the injury through the extraction site was necessary in three of the seven patients. Overall postoperative complication rate in the group sustaining an injury was 25 % [55]. Others have examined the rate of trocar injuries to the vasculature at the time of laparoscopy [56, 57]. One series examined the number of trocar injuries reported to the FDA through the Center of Devices and Radiological Health [56]. In this study, the authors found 408 cases of vascular injury reported to the FDA as a result of trocar insertion. It is impossible to know the actual incidence from this study without a denominator; however, they did note that 26 of the 408 patients died as a result of the injury for a mortality rate of around 6 % [56]. The actual incidence of trocar injury was reported by Larobina and Nottle in a case series report as well as a literature review [57]. Here they found no major vascular injuries in their case series of 5900 patients and a rate of 0.04 % in a literature review which included over 760,000 patients [57]. They concluded that vascular injuries at the time of trocar insertion are rare and can be eliminated by an open, Hasson access technique [57].

While it is difficult to know the exact impact of vascular injuries and blood loss on postoperative outcomes, there is enough data to warrant meticulous attention to hemostasis. There are a myriad of minimally invasive and open instruments available for hemostasis during colorectal procedures. These devices can be used for adhesiolysis, dividing embryological attachments, ligating mesentery, and even ligating named vascular pedicles. The technology continues to evolve at a rapid pace. A recent Cochrane review looked at various commercially available instruments used for laparoscopic colectomy. It evaluated six separate randomized controlled trials including a total of 446 patients [58]. These trials evaluated laparoscopic staplers and clips, as well as electrothermal bipolar vessel sealers (EBVS), monopolar electrocautery scissors (MES), and ultrasonic coagulating shears (UCS) [58]. This review found significantly less blood loss in studies using UCS compared to MES. Overall, hemostatic control was found to be improved in UCS and EBVS over

MES. No definite conclusion on the cost difference between these three instruments was made in this review. This review also found that laparoscopic staples/clips used for pedicle ligation in colectomy were associated with more failures in vessel ligation and cost more when compared to EBVS [58]. Additionally, a randomized clinical trial comparing the cost and effectiveness of bipolar sealers versus clip and vascular staples for laparoscopic colorectal resection found that bipolar sealers reduced both the time spent and the cost of disposable instruments for achieving vascular control [59]. Another prospective randomized trial by Marcello and colleagues found increased failure rates in cases where vascular staplers and clips were used for pedicle ligation [60]. However, the amount of blood loss associated with device failure was higher in those using EBVS for pedicle ligation [60].

The choice of ideal device remains largely up to surgeon preference. There are now multiple instruments capable of 7 mm vessel sealing with various other capabilities. Based on the current available literature, electrothermal bipolar vessel sealing allows for faster operating times, less blood loss, and less sealing failure [58]. However, sealing failure with an energy device often leads to more blood loss than sealing failure with the use of clips and vascular staplers [60]. It is our practice to take vascular pedicles with an electrothermal bipolar vessel sealing device. For device failure or inadequate seal, we favor the use of clips or alternatively an endo-loop, as blindly sealing vessels in a crimson field is often fraught with complication. In the setting of a known atherosclerotic vessel, the application of a vascular stapler should be considered.

Urologic Injuries and Their Management

Ureteral Injury

One of the most dreaded complications related to colorectal surgery is ureteral injury, which thankfully remains an exceedingly rare occurrence. Iatrogenic ureteral injury has a documented incidence of 0.3–1.5 % in most studies. A retrospective analysis of over two million colorectal surgical procedures found an incidence of 0.28 %; however, a significantly higher incidence was found in the latter time period of this analysis, suggesting a trend toward increasing rate of this complication [61]. Risk factors for ureteral injury in this study included the presence of rectal cancer, adhesions, metastatic cancer, weight loss/malnutrition, and teaching hospitals. A study by Palaniappa et al. examined their series of over 5000 patients undergoing colectomy for various indications [62]. They found a significantly higher rate of ureteral injury associated with laparoscopic colectomy compared to open (0.66 % versus 0.15 %, $P<0.05$) [62]. They also found that female sex, increased operative blood loss, and reoperation conferred an increased risk of iatrogenic injury [62]. Ureteral injuries were associated with higher morbidity and mortality, longer length of stay, and higher hospital charges by over $30,000 [61]. It does appear that experience and working through the learning curve lead to a decrease in these types of iatrogenic injuries [63].

Preoperative or intraoperative ureteral catheterization is sometimes used to aid in identification of the ureters and subsequent injury. Most data suggest that placement of ureteral stents neither reduces the incidence of injury nor ensures intraoperative identification of injury [64]. In an NSQIP analysis, there was an increasing trend of ureteral stent use over time from 1.1 to 4.4 % from 2005 to 2011 [65]. Independent predictors of stent utilization included diverticular disease, LAR and APR, recent radiation therapy, and more recent year of operation [65]. After adjustment for baseline patient and operative characteristics, there were no statistically significant differences in any primary or secondary endpoints, including overall renal complications. There was, however, a statistically significant increase in length of stay associated with stent utilization, which was also observed by Halabi and colleagues [61, 65].

Early identification of injury is paramount in minimizing morbidity and preserving renal function. Diagnosis of a suspected injury can be confirmed with an on-table intravenous pyelogram (IVP), retrograde injection of methylene blue, intravenous administration of methylene blue or indigo carmine, or ureteral catheter contrast administration. Injuries can be classified as a laceration, ligation, devascularization, or energy related. Transection and laceration are repaired based on location of injury. General principles include use of absorbable suture (to prevent stone formation), tension-free spatulated anastomosis over an indwelling stent, and placement of a closed suction drain. For those injuries in the proximal one-third (2 % of injuries), repair depends on length of the damaged segment. Simple spatulated ureteroureterostomy (UU) is the preferred method of repair. For additional mobilization, a nephropexy can be performed with fixation to the psoas tendon. Bowel interposition can be utilized for long-segment damage. Additionally, a psoas hitch or Boari flap can be used to reach the upper ureter; however, these procedures are more commonly used for injuries of the middle or distal third. Injuries to the middle third account for 7 % of ureteral injuries, and the preferred method of repair is via ureteroureterostomy for short-segment injury. A psoas hitch or Boari flap should be used if a tension-free anastomosis is not possible, with the Boari flap preferred for injuries spanning longer and more proximal distances. Lastly, a transureteroureterostomy (TUU) can be performed with anastomosis to the contralateral uninjured ureter. Injuries to the distal one-third of the ureter are preferentially repaired with ureteroneocystostomy. A Foley catheter should be left in place for 7–14 days with stent removal 4–6 weeks after surgery [64].

Bladder Injury

Bladder injury also presents a significant management challenge for the colorectal surgeon. These injuries can present in a delayed fashion or at the time of initial surgery. Risk factors

include previous operations, radiation treatment, malignant infiltration, chronic infection, and inflammatory conditions. Radiographic diagnosis can be obtained with CT cystogram or fluoroscopic cystogram. Untoward complications of missed bladder injury can include development of a colovesical or enterovesical fistula. Abdominopelvic CT scan with oral and rectal contrast may be performed for accurate diagnosis [64].

Primary repair (cystorrhaphy) with placement of closed suction drains is the preferred approach when injury is immediately recognized. Small extraperitoneal injuries can be effectively treated with 7–14 days of Foley catheter decompression. Larger or intraperitoneal bladder injuries require operative repair. For injuries to the ventral bladder, dome, or posterior bladder away from ureteral orifices, the bladder can be repaired primarily with two-layer mucosal and seromuscular closure using absorbable suture. A third layer, in the fashion of Lembert, can be added for high-risk cases. Permanent suture must be avoided to prevent the long-term development of bladder stones. For injuries involving the posterior bladder or trigone, near the ureteral orifices, inspection for ureteral injury is mandatory via mobilization of the space of Retzius and subsequent anterior cystotomy, allowing for full exposure of the trigone and interior of the bladder. Indigo carmine can then be administered intravenously to aid in identification of ureteral orifices. Posterior repair is then performed through this anterior cystotomy [66]. Delayed diagnosis of urine leak from the bladder is often managed with percutaneous drainage of a urinoma and continued Foley catheter decompression. Finally, it is always prudent to at least consider consultation with specialized services when faced with difficult scenarios and specific complications. This allows for the obvious support with the repair as well as additional advice in difficult scenarios.

Urethral Injury

Perhaps the least frequent intraoperative urologic injury involves those to the urethra. The most common urethral injury during colon and rectal surgery is related to traumatic Foley catheter placement. The exact rate of this injury in the colorectal patient population is difficult to ascertain. Kashefi and others prospectively studied men in their institution over 1 year and found the rate to be 3.2/1000 catheter insertions [67]. After the implementation of an educational program teaching the inserter to investigate for the presence of risk factors such as benign prostatic hypertrophy, the incidence decreased to 0.7/1000 catheter insertions [67]. Direct injuries also occur during extirpative surgery. Many of these patients have a history of radiation therapy and are prone to fistula formation. Intraoperatively, retrograde injection of methylene blue-tinted saline can aid in diagnosis. The most common presentation of a urethral injury is postoperatively by virtue of fistula formation. Cystoscopy, retrograde urethrogram, exam under anesthesia, and CT scan with both oral and rectal contrast help to delineate the location of injury, which has significant impact on reparative options [64].

Primary repair at the time of injury in two layers with absorbable suture is of course the preferred method. In the setting of poor tissue or neoadjuvant radiation, utilization of an omental flap or local tissue flap can reduce the risk of postoperative fistula formation. In the case of extensive urethral loss recognized at the time of surgery, local tissue flaps may be used to aid in reconstruction. If repair is not feasible, a suprapubic catheter should be placed and repair can be performed after several months [64].

Injuries recognized postoperatively with resultant fistula formation must be staged according to location, size, and history of radiation treatment. Spontaneous closure of rectourethral fistula is extremely rare [68]:

Stage 1—low (<4 cm from anal verge, nonirradiated)
Stage 2—high (>4 cm from anal verge, nonirradiated)
Stage 3—small (<2 cm diameter, irradiated)
Stage 4—large (>2 cm diameter, irradiated)
Stage 5—large (ischial decubitus fistula)

Principles of repair include transection and closure of fistulas and placement of interposed local or regional tissue flaps or grafts [69]. Fecal diversion is recommended for stages 3 through 5, usually in advance. Reparative choices depend on local tissue integrity and staging. A suprapubic catheter is recommended in addition to a Foley catheter for adequate decompression and drainage [70]. Transanal advancement flap alone can be performed for stage 1 fistulas or in combination with other techniques for higher-stage fistulas [71]. Perineal approaches and transanal or transsphincteric approaches have also been described [72, 73]. Other operative approaches include harvest and interposition of regional myofascial flaps [74, 75]. Muscle interposition repairs can be used alone or in combination with abdominoperineal pull-through with resection of the fistula and hand-sewn colo-anal anastomosis [76].

Postoperative Management Decisions that Contribute to Postoperative Complications

IV Fluid Management

There is little doubt that the administration of intravenous fluids contributes to postoperative complications. In a study published by Lobo et al., 20 patients were randomly allocated to either standard fluid management or a restricted fluid protocol [77]. Patients randomized to a restricted protocol had earlier return of bowel function as measured using radioscintigraphic studies, as well as shorter length of stay and lower rates of complications [77]. While this was a small study, other larger trials examining fluid restriction as part of an enhanced recovery after surgery (ERAS) pathway have clearly shown that fluid restriction is an essential component of these protocols [78–81]. In a meta-analysis of randomized

controlled trials, Adamina et al. found that length of stay was reduced by an average of 2.5 days and postoperative morbidity was 50 % lower in patients managed on an ERAS protocol compared to those receiving standard postoperative care [80]. The authors of this study estimated that one complication was avoided for every 4.5 patients managed on the ERAS protocol [80]. Of course, outside of an ERAS protocol, the management of fluids should be tailored to each individual patient [82]. In support of this principle, a trial of liberal fluid management versus fluid restriction in patients not being managed in an ERAS fashion was published by Mackay and others [83]. In this study, fluid restriction had no impact on early return of bowel function [83]. In contrast, patients in the restricted arm had a slight increase in their postoperative levels of serum BUN and creatinine, which did not reach statistical significance. In general, the data indicate that fluid restriction is a critical part of an ERAS protocol and that patients have improved outcomes when managed on these types of regimented pathways.

Wound Management

While there are no clear guidelines for the postoperative management of wounds, there are some general recommendations that may lead to lower rates of postoperative superficial surgical site infections (SSIs). Dressings are considered a standard of care in the management of surgical wounds, but there has been no standardization [84]. A recent Cochrane review on the topic of wound dressings and their effect on wound infection was published by Dumville and colleagues [84]. In this manuscript, the authors identified 20 randomized controlled trials, all of which had significant methodological problems. Despite the limitations of the studies, the authors performed a thorough review and found no evidence that one type of wound dressing decreased incidence of SSI over any other type [84]. In short, dressing selection should be left up to the operating surgeon and should probably reflect cost and convenience. Table 8-1 lists features of an ideal wound dressing [84].

Some have recently been interested in using new technology to manage wounds. For example, the utility of a negative pressure wound dressing on primarily closed wounds for the prevention of wound infections has been examined [85–87]. In general, the work with negative pressure units is filled with bias, and the role for this technology for the prevention of wound infections remains to be seen.

The etiology of a wound infection is largely unknown. While contamination at the time of surgery contributes to risk for infection, it has been thought that a wound hematoma or seroma may be the inciting event that leads to the postoperative infection in those cases where contamination did not occur. In an attempt to eliminate this fluid collection from the wound, Towfigh and others randomized 76 patients with high-risk wounds to either daily wound probing or standard wound management [88]. Patients treated with daily wound probing had lower rates of SSI (3 % versus 19 %) and shorter postoperative stay by 2 days [88]. While these results were promising, they have unfortunately never been reproduced or expanded to a larger population in general or colorectal surgery. In summary, there is no good evidence that any one wound management strategy is better than another. The choice of management strategies should be based on institutional experience and buy-in of the surgeons involved and should ultimately be incorporated into an institutional SSI reduction bundle which packages all care around the episode of surgery in order to reduce wound infection risk [89–93].

Table 8-1 Features of an ideal wound dressing

1. The ability of the dressing to absorb and contain exudate without leakage or strike-through
2. Lack of particulate contaminants left in the wound by the dressing
3. Thermal insulation
4. Impermeability to water and bacteria
5. Suitability of the dressing for use with different skin closures (sutures, staples)
6. Avoidance of wound trauma on dressing removal
7. Frequency with which the dressing needs to be changed
8. Provision of pain relief
9. Cosmesis and comfort
10. Effect on formation of scar tissue

Bladder Management

Urinary tract infection (UTI) and catheter-associated UTI (CAUTI) are frequently encountered postoperative complications related to colorectal surgery procedures. A study from the NSQIP PUF found the rate of UTI after colorectal resection to be 4.1 % compared to 1.8 % after other general surgery operations [94]. The authors concluded that the actual rate of UTI in colorectal surgery patients is higher than expected by predictive models. Factors that correlated with an increased risk for developing a postoperative UTI included female sex; ASA class >2; procedure of a total colectomy, proctocolectomy, or APR; functional status of partially or totally dependent; and age greater than 75 [94]. Other significant factors such as presence of indwelling catheter, number of catheter days, and incidence of postoperative urinary retention are known to strongly associate with risk for UTI but are unfortunately not included in the NSQIP database. Therefore, while NSQIP database studies indicate that colorectal procedures are high risk, they offer little insight into the modifiable source of this risk.

In 2008, the Centers for Medicare and Medicaid Services (CMS) implemented a policy whereby they would reduce payment for hospitalizations that included a preventable complication [95–97]. Effective for discharges beginning October 1, 2014, CMS instituted a 1 % payment reduction for those hospitals whose ranking falls in the bottom quartile of conditions acquired during the hospital stay [97]. Included

among these hospital-acquired conditions is the surveillance measure of catheter-associated urinary tract infection (CAUTI). Best practices and care bundles have been widely published in attempts to decrease the rates of CAUTI [98, 99]. While CMS has emphasized CAUTI, many in the hospital-acquired infection community point to the limitations of these surveillance definitions. For example, it is clear that a CAUTI is often not relevant to the care of the patient diagnosed after an unindicated urinalysis has revealed the presence of asymptomatic bacteriuria [100, 101]. However, the unintended negative consequences of such a urinalysis cannot be ignored [100, 101]. The unnecessary antibiotic use that often results from this type of test result leads to increased risk exposure to the patient and increased antibiotic pressure on the patient's microbial environment and ultimately contributes to the selection of multidrug-resistant organisms.

Given all of these implications of CAUTI, it makes sense that surgeons pay attention to these measures and contribute our efforts to the improvement of patient safety and reduction of hospital-acquired conditions. The question facing surgeons is how to effectively do this while still managing the patient according to a standard of care. For example, if all catheters are discontinued upon completion of an operation, we will certainly reduce the rate of CAUTI in our patient population. However, Kwaan et al. have found that early removal of the urinary catheter increases rates of urinary retention in patients undergoing pelvic surgery [102]. These high rates of urinary retention lead to increased catheter reinsertion, which likely contributes to an increased rate of urinary tract infection in patients who suffer postoperative urinary retention (POUR) [103]. However, a randomized controlled trial of early catheter removal in patients with an epidural was performed by Coyle and colleagues [104]. Here the authors found no difference in rates of POUR in epidural patients who had their catheter removed on postoperative day number 2 compared to those patients who had their catheters removed after the epidural was removed [104]. The conclusions drawn from these studies must be tempered given the clear limitations of both data and study design. Therefore, before a policy of early catheter removal can be instituted for all patients undergoing colorectal surgery, we must better understand the problem of POUR and implement effective methods to deal with this complex problem.

Pain Management

Perioperative pain is a potent trigger for the stress response that can activate the autonomic nervous system and may contribute to adverse postoperative outcomes. While there is very little evidence that poor pain control itself contributes to worse postoperative outcomes, one study found that hospitals with low patient satisfaction scores related to pain control had higher rates of postoperative mortality compared to similar hospitals [105]. Others have found that poor postoperative pain control after thoracotomy was associated with the development of chronic long-term pain [106]. While it is not clear if poor pain control contributes to those complications colorectal surgeons commonly worry about (anastomotic leak, wound infection, etc.), Lynch and colleagues did find a correlation between high postoperative pain scores and the development of postoperative delirium [107]. In addition, high pain is often treated with high doses of opioids, which increases risk for respiratory depression and other complications related to oversedation [108]. Irrespective of the lack of high-quality data showing a clear relationship between poor pain control and postoperative complications, very few surgeons will argue against the principle of good pain control in order to ensure humane, high-quality postoperative care of all patients.

Because of the many obvious negative implications of poor pain control, many studies have assessed the best route of analgesic delivery. Specifically, many studies have examined intravenous versus epidural delivery of pain medications and have, in general, found that epidural delivery results in improved postoperative pain control [109–113]. Randomized controlled trials of laparoscopic versus open colectomy have found pain scores to be generally decreased in patients undergoing laparoscopic colectomy [114]. Therefore, as laparoscopy becomes more widespread in colorectal surgery, the use of postoperative epidural must be reexamined. In fact, a meta-analysis recently published found that although pain control was improved by the use of an epidural in patients undergoing laparoscopic colectomy, there was no difference in return of bowel function and no impact on length of stay [115]. Other studies have found no real differences between epidural and patient-controlled intravenously delivered analgesia [115–118]. Enhanced recovery after surgery protocols have largely adopted non-opioid-based pain regimens, and more work is focusing on local blocks, such as the transversus abdominis plane (TAP) block, to enhance pain control [119, 120]. Further studies are needed to identify the ideal pain control regimen for patients undergoing laparoscopic and open colorectal surgery. Regardless, it is clear that adequate pain control improves the overall patient experience.

Impact of Hospital Structure on Postoperative Complications

Academic Medical Center

The impact of resident training on patient outcome has long been debated in both the academic and lay press. In fact, Kiran et al. found a correlation between increased rates of complications and resident involvement in patient care [121]. While these results must be interpreted in the light of the limitations within the NSQIP participant use file, they do suggest that resident participation may be potentially detrimental to patient care. However, they also found that resident participation was associated with a lower rate of failure to rescue, indicating that even though patients treated at an academic

medical center may have a slightly higher rate of complications, they have a lower mortality rate as a result of these complications [121]. This is likely related to resident hospital presence at all hours allowing rapidity of assessment and implementation of rescue measures. Others have similarly queried the NSQIP dataset from various years and similarly found that resident participation increases rates of postoperative complications [122–124]. While the NSQIP database controls for many factors of patient morbidity that increase risk for postoperative complications, there are many limitations of the dataset that must be considered prior to drawing hard and fast conclusions. First, missing data fields is a common problem of this database, which limits risk stratification. In addition, there is no control for the attending surgeon's gestalt assessment of risk, which also contributes to operative approach and ultimately to the operation performed.

While the above studies have examined the question of resident impact on outcomes from the binary, yes-no perspective, others have examined this question from the seasonal perspective. In particular, Englesbe et al. examined the rate of complications according to the time of year using the NSQIP dataset [125]. They found that patients treated later in the academic year had lower rates of mortality and morbidity [125]. While these results are intriguing, they still fail to control for confounding variables including differences in the environment that may contribute to complications. In fact, one study of over one million patients undergoing coronary artery bypass grafting examined outcomes by time of year in both academic and nonacademic medical centers [126]. The authors of this study found that rates of complications were higher in the first part of the year, independent of teaching status. However, they found that the rate of mortality following complication, or failure to rescue, was higher in patients treated at nonacademic medical centers. They concluded that a seasonal variation to complications and mortality exists in medical centers and cannot be explained by the presence of trainees alone [126]. In summary, it is not entirely clear that trainee presence is independently associated with postoperative complications. Furthermore, mortality rates after major complications seem to be lower in hospitals that have training programs. These findings suggest that more studies are necessary to clearly define the relationship between resident training and patient outcomes, as well as the source of the seasonal variability in postoperative morbidity and mortality.

Surgical Volume and Postoperative Complications

Much has been written on the effect of surgical volume on complications. On the surface, these papers seem to be largely self-serving works that conclude low-volume surgeons have higher rates of mortality and complications, which would necessitate referral to higher-volume surgeons. While this may be true on some level, a more critical evaluation of the literature reveals that there is a very complex interplay between the volume of the surgeon and the volume of the institution. This interplay can be seen quite nicely in two papers written by Dr. Birkemeyer and colleagues [127, 128]. In these papers, he first described a relationship between hospital volume and postoperative mortality for specific complicated operations—pancreatectomy, esophagectomy, etc. [128]. In general, they found that the rate of mortality after all resections, including proctectomy, decreased as the volume of the procedure increased at the hospital. The group then expanded this work and looked at the impact of provider volume on these mortality rates [127]. They found that provider volume could mitigate some of the effect of the institutional volume for some operations. However, not all of the effect on mortality could be explained by provider volume. The end result is a complex relationship between provider and institutional volume, suggesting that the system in which a patient undergoes an operation contributes to outcomes. This type of work has been demonstrated multiple times using many different datasets over the years [129–136]. While most of this work has indicated that higher volume is associated with improved outcomes, little work has been accomplished in understanding the mechanism behind this complex observation. Specifically, it would be interesting to truly understand the impact of the hospital system on outcomes. In recent work, Ghaferi et al. examined the features of hospital systems that correlate with low rates of mortality after major complications [44]. In this study from the Nationwide Inpatient Sample database, the authors found that teaching hospitals with more than 200 beds, increased nurse-to-patient ratio, and with a high level of technology had lower rates of failure to rescue [44]. While the results were not completely surprising, this study lays the groundwork for future investigations into how systems of care directly impact patient outcomes.

Prevention and Management of Specific Complications

Wound Complications

Wound complications and, specifically, surgical site infections (SSIs) are among the most common source of nosocomial morbidity for patients undergoing surgical procedures. SSIs are associated with increased hospital length of stay, increased risk of mortality, and decreased health-related quality of life [137, 138]. This risk is significantly increased in those patients undergoing colorectal surgery [139]. This of course is related to the clean-contaminated nature of many colorectal procedures and exteriorization of the bowel. Wound infections are commonly thought of as occurring in the superficial tissues, deep tissues, or organ space. The bulk of this discussion will focus on the prevention and treatment of superficial surgical site infection. However, all principles are applicable to deep surgical site infections and many are also applicable to organ-space infections.

It has been estimated that an SSI adds between $10,000 and $25,000 to the care of a patient depending on extent of infection [140, 141]. Given the implications of SSI on both patient outcomes and healthcare costs, much effort has been directed toward the prevention of these complications. Preoperative, perioperative, and postoperative interventions have been implemented in an attempt to decrease the rates of wound infections in all patients.

Preoperative Considerations

There are a myriad of patient-specific factors that predispose to an increased risk of perioperative complications. The number of people classified as overweight [body mass index (BMI) = 25 to <30 kg/m^2] or obese (BMI ≥ 30 kg/m^2) is at pandemic proportions. The prevalence of obesity is increasing and significantly influences overall survival of the general population. The most recent data from the United States show that 40 % of adult men and 30 % of women fall within the overweight category [142]. Elevated BMI has been a validated risk factor for SSIs, with some reporting SSI rate as high as 60 % among obese patients [143–148]. However, BMI does not account for all risks associated with wound infection. In an attempt to better quantify the impact of BMI on both medical and surgical complications, there has been recent interest in the role of waist circumference (WC) and waist-to-hip ratio (WHR) on the development of cardiovascular events, as well as specifically the relationship between these measurements and perioperative outcomes of colorectal surgery. Waist circumference is thought to better reflect abdominal adiposity, including the subcutaneous fat layer, and intra-abdominal visceral adiposity. The INTERHEART study found that increased WC and WHR was predictive of myocardial infarction. To evaluate the effect of WC and WHR on surgical complications, a prospective, multicenter, international study of 1349 patients undergoing elective colorectal surgery was performed. Increased WHR was identified as an independent predictor of intraoperative complications, conversion, medical complications, and re-interventions, whereas increased BMI was a risk factor only for abdominal wall complications [149].

Another well-established risk factor for SSI is administration of allogeneic blood transfusion [139, 150, 151]. It is hypothesized that the underlying mechanism is related to transfusion-induced immunosuppression [150]. In addition to the deleterious effect that transfusion may have on disease-free survival in colorectal cancer patients, reduction in SSI risk is another compelling reason to use blood judiciously in colorectal surgery patients [152].

Perioperative Interventions

The role of mechanical bowel preparation in the prevention of SSIs has been extensively studied and debated. The data are conflicting, and oftentimes the arguments for or against bowel preparation relate more to personal preference than to evidence. That being said, much has been written on this topic. For example, there have been three recent meta-analyses of RCTs evaluating the need for mechanical bowel prep prior to surgery. One study evaluating nine RCTs demonstrated a significant increase in the percentage of anastomotic leak in prepared patients (6.2 % versus 3.2 % [OR 2.03]) [153]. An update of this analysis failed to detect significant differences in anastomotic leakage or SSI between those patients receiving and not receiving bowel preps [154]. A second meta-analysis similarly found no difference in anastomotic leakage rates; however, analysis of secondary outcomes yielded a significant difference in SSI, favoring no MBP [155]. Despite these results, the majority of colorectal surgeons still favor the use of mechanical bowel prep. Reasons for this include improved handling of a prepared colon and reduction of stool burden proximal to a fresh anastomosis. Interestingly, recently, a large retrospective review of nearly 10,000 patients did not find any difference in SSI between those with and without MBP. However, the use of oral antibiotics alone was associated with a 67 % decrease in SSI, and oral antibiotics plus mechanical bowel prep were associated with a 57 % decrease in SSI. Additionally, hospitals with higher rates of oral antibiotics had lower SSI rates [156].

Skin preparation has also been extensively examined in relation to wound infection risk. Various skin prep techniques and products are available for colorectal procedures, but clear evidence supporting one over another is lacking. In one randomized controlled trial, the use of chlorhexidine-alcohol rather than povidone-iodine was shown to significantly reduce both superficial surgical site infections and deep incisional infections but had no demonstrable effect on organ-space infections [157]. Another group performed a sequential implementation study in which different skin preparation agents were serially used over the course of a defined time period [158]. The authors of this study found the lowest rates of SSI in the time frame that used iodine povacrylex in isopropyl alcohol, which subsequently led to institutional adoption of this skin prep agent [158]. This is a perfect example of classic quality improvement work characterized by the FOCUS-PDCA process (Figure 8-2) [159–161]. This quality improvement model facilitates concrete steps toward a defined goal and ultimately implementation of change to enhance patient care. However, it is important to note that quality improvement is an iterative process. As implied in Figure 8-2, the FOCUS-PDCA process is a cycle that repeats itself. This cycle allows us to always search for a better "best practice."

Another relatively straightforward intervention at the time of operation that may prevent superficial SSI is the use of a wound protector. While there are conflicting data regarding the utility of these devices in preventing wound infections in abdominal surgery, a recent randomized study of 130 consecutive patients undergoing elective, open, colorectal surgery found that the use of a wound protector was significantly

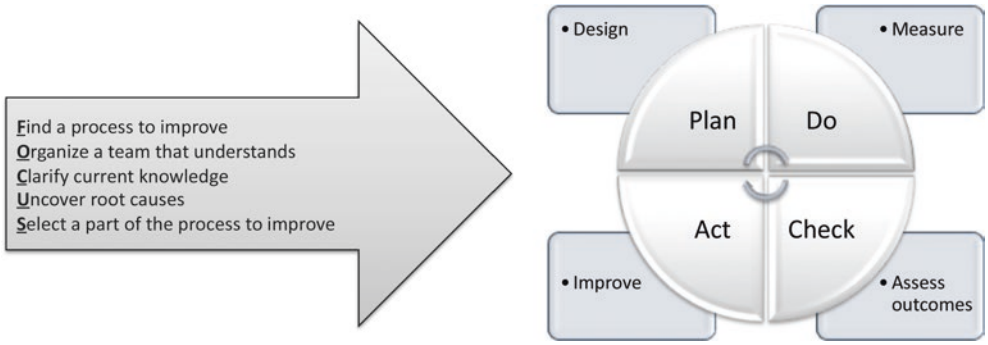

FIGURE 8-2. FOCUS-PDCA cycle is shown. The key to a successful quality improvement process is the continuous assessment and process improvement implied by the cycle.

associated with reduced incidence of incisional SSI [162]. A recent meta-analysis supported these results, concluding that the use of a dual-ring wound protector is associated with decreased risk for SSI [163].

In addition to interventions aimed directly at reducing microbial burden, treatments that improve oxygen delivery to the wound have also been examined in the context of SSI prevention. Murray et al. [164] performed a review of level 1 evidence looking at non-pharmacologic modalities for decreasing the incidence of SSI. These include easily implemented, cost-effective interventions with a low-risk profile such as administration of supranormal oxygen, active rewarming strategies, and adjustment in wound closure techniques. Several prospective randomized trials have attempted to define the impact of supranormal levels of oxygen during anesthesia on SSI [165–168]. A meta-analysis of such trials demonstrated a significant decrease in SSI with the use of 80 % FIO2 in the perioperative setting, favoring the use of perioperative hyperoxia. In contrast, a recent multicenter study [PROXI] that randomized patients to receive 80 % FIO2 intraoperatively and 2 h postoperatively versus 30 % FIO2 in a similar fashion found no difference in outcomes [168]. Of note, none of these studies reported any adverse events attributable to the administration of supranormal levels of oxygen [164]. Another readily available intervention that has been shown to reduce SSI in colorectal surgery patients involves the application of an active warming strategy perioperatively [169, 170].

Multiple reports have demonstrated the utility of closing the midline wound with a suture length-to-wound length ratio of at least 4 [171]. This technique mandates taking either >10 mm fascial bites at greater intervals than previously recommended or alternatively smaller bites of the fascial edge (5–8 mm) in closer intervals. These techniques were compared in a randomized controlled trial which demonstrated a significant increase in SSI and incisional hernia when utilizing the former approach [172]. Specific to colorectal surgery, ileostomy closure poses a unique challenge with regard to infection. In this setting, purse-string closure of ileostomy wounds has been significantly associated with reduced SSI rate in a meta-analysis of three RCTs [173, 174].

In summary, multiple low-risk perioperative interventions can be taken that likely improve short-term outcomes. This phase of care should not be neglected when implementing a bundle of care designed to decrease risk for surgical site infection. Such a bundle might include bowel preparation with oral antibiotics, skin preparation with a chlorhexidine-based agent, hyperoxygenation, active warming, and meticulous closure with careful attention to tension and hemostasis, all of which together may contribute to improved outcomes.

Management of Superficial Surgical Site Infection

Given the enormity of the problem of surgical site infections, it is clear that the best management strategy is one of prevention. Regardless of the interventions taken to prevent these hospital-acquired infections, it seems that the most efficient method involves standardizing the practice to include a bundle of care that is included for every operation. Dr. Cima and others have recently published their experience on a surgical site infection reduction bundle at their institution in Rochester, MN. They have found a reduction of surgical site infections from 9.8 % pre-bundle to 4.0 % after the bundle implementation [92]. Monitoring of compliance with the care bundle is also critically important. As shown by Waits et al., compliance with all parts of a bundle correlates with a lower risk of wound infection (2.5 % in those hospitals with 100 % compliance compared to 17.5 % in those hospitals that were the most noncompliant) [175]. We have similarly implemented a surgical site infection reduction bundle in our hospital and have seen our rate of SSI as monitored by NSQIP to drop into the “as expected” range with the most recent site report showing our rate of SSI in colorectal surgery to be in the second decile (data not shown). The adoption of bundled care ensures all members of the surgical team are focused on the safety of the patient and gives the team a template from which to work.

Despite all attempts to prevent surgical site infections in colorectal surgery, the average institution will continue to see rates of infections near 10 %. Therefore, understanding

the principles of treatment is critical. For an uncomplicated superficial surgical site infection, the standard treatment is drainage of the infection and local wound care without the routine use of antibiotics [176–178]. If patients exhibit signs and symptoms of shock, one must suspect the presence of a deeper infection. This type of infection may involve the deeper layers of the wound (muscle and fascia) or may even involve the organ space. Aggressive interventional therapy is often required to adequately treat a deep surgical site infection and organ-space infections may require reoperation as well. It is critical that the surgeon stay intimately involved in all aspects of the patient's care and also remain vigilant as the best treatment of these infections is often through early identification and infection control.

Cardiovascular and Respiratory Complications

Additional postoperative complications befall those undergoing colorectal surgery. These include cardiovascular complications, which as mentioned have an increased incidence in those patients with an elevated BMI, as well as more recently found, elevated waist-to-hip ratio. In the previously mentioned study of 1349 patients, which identified elevated waist-to-hip ratio (WHR) as a predictor for postoperative complications, the incidences of stroke, deep venous thrombosis, myocardial infarction, congestive heart failure, and pulmonary embolism were all less than 1 %. All complications, to include cardiovascular and respiratory complications, as well as sepsis and septic shock, were previously shown to be decreased in those patients undergoing laparoscopic colorectal procedures compared to those patients undergoing similar procedures in an open fashion [34, 179].

Postoperative venous thromboembolism carries a current prevalence of 1.4–2.4 % in colorectal surgery patients and is one of the most important potentially preventable conditions leading to increases in morbidity, mortality, hospitalization length, and hospital charges [180–182]. A recent study of 116,029 patients utilizing the ACS NSQIP database analyzed the incidence, risk factors, and 30-day outcomes of VTE in patients undergoing colorectal procedures [183]. Risk-adjusted analysis for preoperative factors associated with DVT included age greater than 70, African American race, ASA score >2, hypoalbuminemia, disseminated cancer, steroid use, and obesity. Additionally, open colorectal procedures had a higher risk of postoperative DVT compared to laparoscopic procedures, as did emergently admitted patients, ulcerative colitis on pathology, and anesthesia length greater than 150 min. Similarly, with regard to PE, risk-adjusted analysis found that age greater than 70, emergency admission, open surgery, hypoalbuminemia, steroid use, and obesity all conferred a significantly increased risk of postoperative PE. Additionally, as expected, mortality risk is significantly increased among those patients diagnosed with PE. This analysis also found that the majority of VTE and PE events occurred during the first week after surgery; however, interestingly, they also found that 34.6 % and 29.3 % of patients diagnosed with VTE and PE, respectively, were diagnosed after discharge [183].

These data underscore the importance of VTE and PE prophylaxis in the perioperative setting and also suggest a possible role for anticoagulating after discharge. It is our practice to administer 5000 units of unfractionated heparin (UFH) prior to skin incision and to immediately implement additional prophylaxis to include UFH or LWMH, on postoperative day 1, provided there are no contraindications. We do not routinely anticoagulate after discharge; however, this practice should be considered as we evaluate the most recent literature. Specifically, a recent randomized prospective analysis evaluating 1-week versus 4-week prophylaxis in patients undergoing laparoscopic colorectal surgery for colorectal cancer found a significant reduction in rates of VTE among those undergoing 4-week prophylaxis with LMWH with similar rates of bleeding between the two groups [184].

Mortality and Failure to Rescue

While postoperative mortality is uncommon after elective colorectal surgery [34, 35], it would be remiss to not address this particular outcome as the patient population ages and becomes higher risk. Fortunately, even in the oldest patient populations undergoing elective colectomy for colon cancer, the rate of mortality is at most 4 % in hospitals participating in the NSQIP program [185]. Given this relatively low rate of postoperative mortality, it is worth considering what leads to death after surgery. In general, mortality after elective surgery does not occur in isolation but rather follows another major complication. In fact, the Agency for Healthcare Research and Quality (AHRQ) has defined death rate among surgical inpatients with serious treatable complications as a patient safety indicator in order to track this metric across institutions. Failure to rescue is defined as death per 1000 surgical discharges among patients aged 18–89 with serious treatable complications such as deep vein thrombosis/pulmonary embolism, pneumonia, sepsis, shock/cardiac arrest, or gastrointestinal hemorrhage/acute ulcer [186]. Failure to rescue is considered a measure of the system of care in which a patient is treated and was discussed previously in relation to the impact of resident involvement on postoperative outcomes at academic medical centers. Sheetz and colleagues examined failure to rescue rates across the state of Michigan using the Michigan Surgical Quality Collaborative [187]. Failure to rescue rates varied by hospital even when controlling for differences in patient characteristics, and rates of complications were highest in the hospitals with the highest mortality [187]. These results suggest that failure to rescue is

more related to the system of care than to the patient population. Ghaferi et al. similarly found that systems-related factors such as number of hospital beds, teaching status, nurse-to-patient ratio, and high technology utilization correlated with low failure to rescue rates [44]. More research is necessary to further delineate both risk and mitigating factors for failure to rescue after major complications.

Long-Term Complications

Many colorectal surgery interventions result in long-term physiological changes for patients. Effective management and patient counseling require a thorough understanding of potential long-term complications and their natural history.

Genitourinary Complications

Bladder dysfunction following colorectal surgery is most commonly related to extirpative procedures in the region of the autonomic pelvic plexus. Abdominoperineal resection and low anterior resection have incidences of postoperative bladder dysfunction of nearly 50 % and 15–25 %, respectively [188]. The most common sequel of autonomic nerve damage during colorectal surgery is parasympathetic detrusor denervation, resulting in impaired contractility of the bladder. A majority of patients will regain the ability to empty the bladder; however, this can take up to 6 months. In the interim, the bladder is managed with clean intermittent catheterization. If careful bladder care is neglected, deleterious effects such as hydronephrosis, urinary reflux, pyelonephritis, and declining renal function may ensue [189]. The use of urodynamics allows for objective measurements to identify those patients at risk, and treatment must be highly individualized [189].

Fertility Complications

Female patients undergoing pelvic procedures should be engaged in a thoughtful discussion preoperatively of the potential risk for fertility problems. A meta-analysis found a postoperative infertility rate of 48 % after restorative proctocolectomy for ulcerative colitis, compared to 15 % preoperatively [190]. Additionally, a systematic literature review was undertaken to evaluate the impact of restorative proctocolectomy on sexual function, urinary function, fertility, pregnancy, and delivery in patients with ulcerative colitis. Infertility rates of 12 % before surgery and 26 % after surgery were reported among 945 patients in seven studies [191]. However, some authors contend that this is more likely related to the disease process itself, rather than the type of surgery performed. A cross-sectional study of FAP patients found no association between fertility problems and type of surgery but did report an increased risk of fertility difficulty in women undergoing surgical procedures earlier in life [192].

Bowel Dysfunction

Pelvic surgery that includes restoration of bowel continuity is not only technically complicated but introduces new physiology to the life of the patients. For example, low anterior resection syndrome includes a variety of symptoms, including fecal incontinence, urgency, frequent bowel movements, and clustering of bowel movements [193]. When undergoing a procedure for rectal cancer, it is often assumed that restorative and sphincter-sparing techniques afford patients a quality of life, which is superior to that of a permanent stoma, with equivalent oncological outcome. This has been challenged by recent inquiries comparing patients' quality of life postoperatively following low anterior resection and abdominoperineal resection for rectal cancer. Certain prospective studies found better cognitive and social function, as well as less symptomatology with respect to pain, sleep disturbance, diarrhea, and constipation in those undergoing abdominoperineal resection. Those undergoing low anterior resection reported better sexual function; however, 72 % reported some degree of fecal incontinence [194]. A recent Cochrane review further calls into question that the quality of life (QoL) with a permanent stoma is inferior to the QoL of those with restored bowel continuity. This review did not find evidence that the QoL after anterior resection is superior to that of patients who had undergone abdominoperineal resection or Hartmann's procedure [195]. This lack of significance led some authors to surmise that this was in direct relation to bowel function postoperatively. Indeed, 50–90 % of patients undergoing sphincter-sparing low anterior resection have some degree of bowel dysfunction postoperatively [196, 197]. Using a validated LARS score [198], Juul et al. found that the quality of life after rectal cancer surgery is closely associated with the severity of the low anterior resection syndrome [193].

The etiology of the symptoms constituting LAR syndrome is unknown; however, it is often manifest by some degree of fecal or gas incontinence, clustering of bowel movements, frequency, and urgency. The severity of symptoms also seems to correlate with tumor height more than 5 cm, total mesorectal excision, and patient treatment with radiotherapy [199]. In fact, Marijnen et al. found that short-term preoperative radiotherapy led to significantly slower recovery from defecation problems, a negative effect on sexual functioning in males and females, as well as more ejaculation disorders and erectile functioning in males, when compared to those patients who did not undergo preoperative radiotherapy [200]. This did not, however, affect health-related quality of life in their study. Interestingly, when patients who underwent low anterior resection versus abdominoperineal resection were compared, those who underwent APR scored better

on physical and psychologic dimensions of quality of life [200]. An additional randomized controlled trial found that a short course of preoperative radiotherapy increased male sexual dysfunction, as well as an increased level of fecal incontinence [201]. Taken together, the risk of bowel dysfunction after surgery can be directly attributed to difficulties with symptoms related to the low anterior resection syndrome. While previous reports have assumed that the quality of life with restorative and sphincter-sparing procedures is greater than the quality of life with a permanent stoma, this is not always the case. When evaluating a patient with rectal cancer, specifically one who qualifies for neoadjuvant treatment, an earnest conversation must be had regarding postoperative functional outcomes.

Impact of Postoperative Complications on Oncologic Outcomes

It is clear that postoperative complications carry implications for short-term quality of life and negatively impact the cost of care. In addition, there is evidence that postoperative complications impact long-term oncologic outcomes [202, 203]. While the exact mechanism of the impact on long-term survival is unclear, it seems likely that postoperative complications result in either delay in receiving or complete omission of chemotherapy in patients with clear indications for systemic treatment. Hendren and colleagues used the SEER-Medicare database from 1993 to 2005 to examine risk for chemotherapy omission [203]. Patients who suffered postoperative complications were more likely to have chemotherapy omitted, but this was unable to be correlated with long-term survival [203]. Tevis and colleagues looked at this question in patients undergoing surgery for rectal cancer [202]. In this cohort, patients with postoperative complications had worse long-term survival than did those with no complications. Postoperative complications independently correlated with decreased overall survival even in patients who received chemotherapy, suggesting that in addition to omission of chemotherapy, complications may otherwise lead to poor long-term survival [202]. While no single study has definitively answered the question, most have found similar negative correlations between postoperative complications and long-term survival, suggesting that there is a relationship between the two. Further work is required to fully understand this relationship.

Conclusion

Postoperative complications after colorectal surgery are common. While we should strive to make postoperative complications, so-called never events, given the imprecise and uncontrollable nature of our profession, it is unlikely that we will achieve such a status. Therefore, we must have a good understanding of the issues related to these complications and be able to work through the implications of these complications. Research to better understand risk factors and preoperative risk mitigation may continue to lead to improved outcomes. How risk modulation can be achieved with surgical approach and intraoperative management must also be examined if we want to continue to improve outcomes. While quality improvement efforts are difficult and not always rewarding, it is clear that continued focus on preventing postoperative complications is beneficial not only to the patient's short-term health and quality of life but will also deliver downstream benefits such as improved long-term physiologic and oncologic outcomes. Finally, it is self-evident that improvements in short-term outcomes will have a positive impact on the healthcare delivery system by decreasing costs associated with postoperative complications.

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