Invited Commentary

Evolving Colon Injury Management: A Review

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The colon is the second most commonly injured intra-abdominal organ in penetrating trauma. Management of traumatic colon injuries has evolved significantly over the past 200 years. Traumatic colon injuries can have a wide spectrum of severity, presentation, and management options. There is strong evidence that most non-destructive colon injuries can be successfully managed with primary repair or primary anastomosis. The management of destructive colon injuries remains controversial with most favoring resection with primary anastomosis and others favor colonic diversion in specific circumstances. The historical management of traumatic colon injuries, common mechanisms of injury, demographics, presentation, assessment, diagnosis, management, and complications of traumatic colon injuries both in civilian and military practice are reviewed. The damage control revolution has added another layer of complexity to management with continued controversy.

THE MANAGEMENT OF colon trauma has evolved significantly over the last 200 years. During the Civil War, soldiers with colon injuries were treated expectantly with the majority of them dying from infection and sepsis. During World War I, the management shifted toward primary repair, but the mortality from colon injuries remained high, approaching 60 to 75 per cent.[1] In light of reports by Ogilvie regarding the experience of the British troops in Africa, the U.S. Office of the Surgeon General in 1943 mandated exteriorization of the injury or repair with proximal diversion as the treatments of choice for colon injuries.[2–5] Mortality rates decreased to 30 per cent toward the end of World War II, possibly because of changes in the management of colon trauma, but improved antibiotics, advances in surgical techniques and instruments, and improved evacuation times also likely played a role.[6, 7] Although mortality rates decreased, complications including wound infections, intra-abdominal abscess, evisceration, and colostomy retraction occurred in nearly all patients.[7]

Despite these complications, mandatory colostomies for colon injuries remained unchallenged as the standard of care until the late 1970s. In 1979, Stone and Fabian[8] published a landmark article reporting the first randomized, prospective trial on patients with traumatic colon injuries that suggested that primary repair was superior to a diverting colostomy in patients with colon injuries. There were significant exclusion criteria, however, including hypotension, hemorrhage greater than 1 L, more than two organ systems injured, significant peritoneal contamination, time to operation greater than eight hours, destructive colon injuries requiring resection, and large losses of the abdominal wall. Patients excluded subsequently underwent obligatory ostomy. They found higher infectious rates (especially intraperitoneal abscess), longer hospital stays, higher cost of care, and higher overall morbidity in patients managed with diverting colostomies. In 1991, Chappius et al.[9] performed a second randomized prospective trial on colon injury management but did not exclude patients who had contraindications to ostomy established by Stone and Fabian. They found no difference in morbidity between patients managed with primary repair and those managed with diversion despite including destructive injuries. They concluded that no single risk factor including penetrating abdominal trauma index (PATI) scores, transfusions, shock, and others could be used to predict increased morbidity from primary repair and that either primary repair or

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Editor's Note: The military surgical experience has long been a source of valuable information on the care of the injured. The authors, all of whom are from the military, review the management of colon injuries and the evolution of current thought and practice in caring for these wounds.

resection and anastomosis should be considered for treatment in all civilian patients with penetrating colon injuries.[9]

Although there is a consensus that the majority of civilian colon trauma should be managed by primary repair, it is unclear if military trauma should use liberal primary repair and anastomosis. Military injuries often include high-velocity weaponry and improvised explosive devices that cause extensive fragment injuries, soft tissue loss, multiple associated injuries, and significant burns.[1] A higher percentage of colon injuries are destructive, resulting in more colon resections compared with primary repairs.[10] Compared with upward of 75 per cent primary repair in civilian trauma, only approximately 20 to 34 per cent of colon injuries during recent armed conflicts have been managed with primary repair.[7, 10–12] Additional factors that must be considered include air evacuation over long distances, triage issues with potential delay of care, higher Injury Severity Score (ISS), limited blood products, and multiple surgeons managing patients at different echelons of care.

Successful colon injury management revolves around understanding the risk factors and identifying the patients who are and are not appropriate for primary repair or anastomosis. The consensus of key risk factors and ideal surgical technique has evolved over time. Primary repair and anastomosis with devastating results were followed with mandatory diversion. Swinging the pendulum again, primary repair and anastomosis are at the forefront. Modern trauma management has greatly benefited from the introduction of damage control surgery. The concept of stabilizing a patient before completing final treatment of injuries has revolutionized trauma surgery, and the role in colon injury management has yet to be determined.

Demographics/Mechanisms of Injury

The colon is the second most frequent organ injured in penetrating abdominal trauma after the small bowel.[6] In the United States, the vast majority of colon injuries are caused by penetrating trauma from gunshot wounds (GSWs). A colon injury is involved in approximately 27 per cent of trauma cases undergoing laparotomy for GSWs with the transverse colon being the segment most frequently injured. In stab wounds, the left colon is more frequently injured because the majority of assailants are right-handed. In penetrating trauma, injury to the colon occurs by direct perforation by bullets or sharp objects.

Blunt mechanisms of injury are thought to be an infrequent cause of colon injuries, ranging from less than 5 to 13 per cent of blunt trauma patients sustaining a colon injury.[13, 14] These injuries are typically associated with other potentially life-threatening injuries to the spleen, liver, small bowel, head, or chest, which make them more difficult to diagnose.[7] Most of these injuries are partial thickness, and only 3 per cent of patients undergoing laparotomy have full-thickness colon perforations.[6] Injuries including serosal tears, contusion injuries, and devascularization injuries occur with or without colonic disruption. The transverse and sigmoid colon may be the most vulnerable because of their anterior position, mesenteric fixation, and compression against the vertebral column.[7]

Colon injuries can occur from endoscopic injuries. Iatrogenic perforations occur in less than 1 per cent of patients undergoing colonoscopy and are most common after a therapeutic intervention to include a biopsy or polypectomy.[15] Specific endoscopic injuries will not be further discussed, but it is important to note that if these injuries require surgical intervention, most can be managed with primary repair.

Classification Systems

Many classification systems of colon injuries have been established to facilitate clinical research and have a uniform system of reference. The PATI was published in 1981 and was designed to access the degree of injury to all abdominal organs and to predict the risk of postoperative complications.[16] For all injuries, a score of 25 is the cutoff above which there is a dramatic increase in postoperative complications, especially septic complications. Although this system is not specific to colonic injuries, it has been commonly referred to as an indication for considering a colostomy.[17–20]

Flint et al.[21] in 1981 developed the Flint Grading Scale for colon trauma. Grade 1 injuries are isolated colon injuries with minimal contamination, minimal delay in operation, and minimal shock. These injuries are generally all managed with primary repair. Grade 2 injuries are through-and-through perforations or lacerations with moderate contamination and possible associated injuries. Grade 3 injuries have severe tissue loss, devascularization, heavy contamination, and can have profound shock. The management of Grade 2 and 3 injuries is more widely debated than for Grade 1.[9, 18, 20–23]

The American Association for the Surgery of Trauma Colon Injury Scale (CIS) was established in 1990 to develop objective criteria for the classification of the severity of the injury and to enable the reliable comparison of results.[24] Injuries are classified as Grades I to V with Grade I injuries being partial-thickness injuries without perforation or hematoma and Grade V being transection of the colon with segmental tissue loss or a devascularized segment of colon. Destructive and nondestructive colon injuries are terms used in the literature based on the two former classification schemes.[25] Nondestructive injuries are those that involve less than

50 per cent of the bowel wall and without devascularized segments. Nondestructive injuries comprise Flint Grades 1 and 2 and CIS Grades I to III. There is strong Class I and II evidence that all should be managed with primary repair in civilian trauma.[8, 9, 22, 26, 27] Destructive injuries involve 50 per cent or greater of colonic circumference compromised or colonic vascular compromise. These are Flint Grade 3 or CIS Grades IV and V. These injuries result from high-velocity GSW, close-range shotgun blasts, and occasional blunt injuries.[7, 25] Unlike nondestructive injuries, these injuries usually require colon resection but do not mandate diversion.

Presentation/Assessment/Diagnosis

There is a wide range of clinical presentations for patients with colonic injury, from patients presenting with minor abdominal pain to others presenting in shock. Advanced Trauma Life Support protocols should be initiated on presentation, beginning with primary and secondary surveys.[28] Resuscitation should be initiated and life-threatening injuries addressed first. The presence and number of penetrating injuries on the abdomen or back should be noted. A seatbelt sign can be a predictor of hollow viscous injury or mesenteric injury.[6] Examination may reveal abdominal tenderness, peritoneal signs, or blood on rectal examination. Look for evidence of foreign bodies in cases of suspected iatrogenic injuries. Retroperitoneal injuries of the colon, usually from penetrating back injuries, can be problematic because they can take up to 24 hours to manifest signs, leading to a delay in diagnosis and increased morbidity.[6, 13] Nonoperative management of a suspected injury not proven with imaging includes mandatory serial abdominal examinations, ideally by the same provider.

Imaging studies include x-ray, ultrasound (focused assessment with sonography in trauma [FAST]), and computed tomography (CT) scan. FAST examinations should be performed as a part of the trauma assessment for the diagnosis of other injuries that would require operative management. Diagnosis of colon injury with FAST is limited to the detection of nonspecific free intraperitoneal fluid and is unreliable in excluding hollow viscous injury or the extent of injury. A retrospective review of 1550 patients with blunt abdominal trauma showed that the sensitivity of the FAST examination was only 38.5 per cent in patients with isolated gastrointestinal injuries.[29] Other limitations including operator experience, body habitus, and the presence of bowel gas and free air can also limit the accuracy of this modality. Diagnostic peritoneal lavage (DPL) has been nearly replaced with FAST examinations and has similar limitations in the diagnosis of colon injuries. DPL may show an increased white blood cell count or alkaline phosphatase as well as the presence of bile or fecal content, but it can also be falsely negative in patients with contained or retroperitoneal perforations.

Upright chest x-ray and an abdominal x-ray may show free air under the diaphragm, which is sensitive in the diagnosis of a hollow viscous injury but not specific for colon injury.[6] CT scan is the imaging modality of choice for the evaluation of hemodynamically stable patients with blunt abdominal trauma. With penetrating abdominal trauma, routine use of CT scan is generally reserved for patients with entry sites in the back and the flank with planned nonoperative management. Anterior injuries and injuries that require operative treatment do not routinely require CT scan.

The most sensitive CT scan finding in colon injury is the identification of the wound tract that extends up to the injured bowel. Other findings include free fluid, extraluminal air, oral and/or rectal contrast extravasation, thickened colonic wall, mesenteric bleeding or hematoma, mesenteric stranding or infiltrates, and intestinal discontinuity. The most specific finding is a defect in the bowel wall. In 2001, Shanmuganathan[30] showed that the helical triple contrast CT including intravenous, oral, and rectal contrast was safe and highly accurate in accessing the wound trajectory and determining if abdominal peritoneal violation had occurred in patients sustaining torso GSWs. They showed a sensitivity of 100 per cent, a specificity of 96 per cent, a negative predictive value of 100 per cent, a positive predictive value of 86 per cent, and an overall accuracy of 97 per cent for predicting the need for laparotomy. The same authors subsequently performed a prospective trial in 2003, which showed that triple contrast CT is reliable (98% specificity and accuracy) to diagnose intra- and extraperitoneal visceral injury. They argued that it should be part of the algorithm to evaluate penetrating torso trauma.[31] Critics maintain that use of intravenous contrast alone may be sufficient with sensitivity and specificity reported at 90 and 96 per cent. Avoiding oral contrast may prevent the delay to diagnosis and potential aspiration risk.[13, 32, 33] Rectal contrast may not provide added benefit, because any patient with free air on a CT requires exploration.[34] Although CT scan may identify patients with colon injuries with high sensitivity and specificity, they can also result in negative laparotomy.[32–34]

The role of laparoscopy in diagnosis and the management of colon injury is currently limited with few scenarios in which it should be applied. Laparoscopy can determine if peritoneal penetration actually occurred if it is unclear on imaging or identify injuries that are difficult to diagnose during laparotomy, like diaphragm injuries. Retroperitoneal injuries are difficult

to diagnose with laparoscopy, and injuries could be missed with significant consequences. A multicenter trial showed the incidence of negative laparotomy after negative laparoscopy was only 25 per cent and the incidence of additional bowel injuries not diagnosed on laparoscopy was 6 per cent.[35] The conservative management of these false-negative patients on laparoscopy could result in greater morbidity and possibly mortality.

Management

Resuscitation should be started immediately in a patient with a suspected colon injury. Initial resuscitation is primarily guided by a patient's hemodynamic status with a goal of maintaining a perfusing blood pressure. Judicious administration of crystalloid fluid is necessary, because large amounts of fluid are thought to increase the risk of anastomotic leaks as bowel edema increases.[36] Excessive volume resuscitation may lead to splanchnic edema, increased intra-abdominal pressure, and decreased mesenteric blood flow. These factors ultimately lead to decreased tissue oxygenation and intramucosal edema and contribute to suture line dehiscence. Blood products such as packed red blood cells (PRBCs) and fresh-frozen plasma have not been associated with increased suture line breakdowns.[36]

There are many factors to consider in determining the most appropriate surgical management of colon injuries. They include degree of injury (destructive *vs* nondestructive injuries), presence of shock or hypotension, degree of fecal contamination, presence of concurrent injuries (PATI greater than 25), prolonged delays from injury to operation (greater than 6 hours), and transfusion requirement (greater than 4 to 6 units PRBCs).[13, 15, 25] Other factors that are no longer thought to influence the type of surgical management include location of the injury (right *VS* left-sided injuries) and mechanism of injury.[37]

Primary Repair

Figure 1 notes an algorithm of colon injury management. The degree of injury, specifically whether it is a simple injury or destructive, is a critical branch point. The majority of all civilian penetrating colon trauma can be managed with primary repair. Indications for primary repair include nondestructive colon injuries irrespective of other risk factors for complications (PATI greater than 25, hypotension, excessive transfusion requirements). Class I and II evidence supports attempted primary repair in all of these patients irrespective of other risk factors for complications including PATI greater than 25, hypotension, AND excessive transfusion requirements.[8, 9, 22, 26, 27, 38, 39] Management includes identifying the perforation, débriding necrotic tissue, and performing a single-layer suture repair of the colon perforation.[13] The suture repair can be buttressed with adjacent omentum.

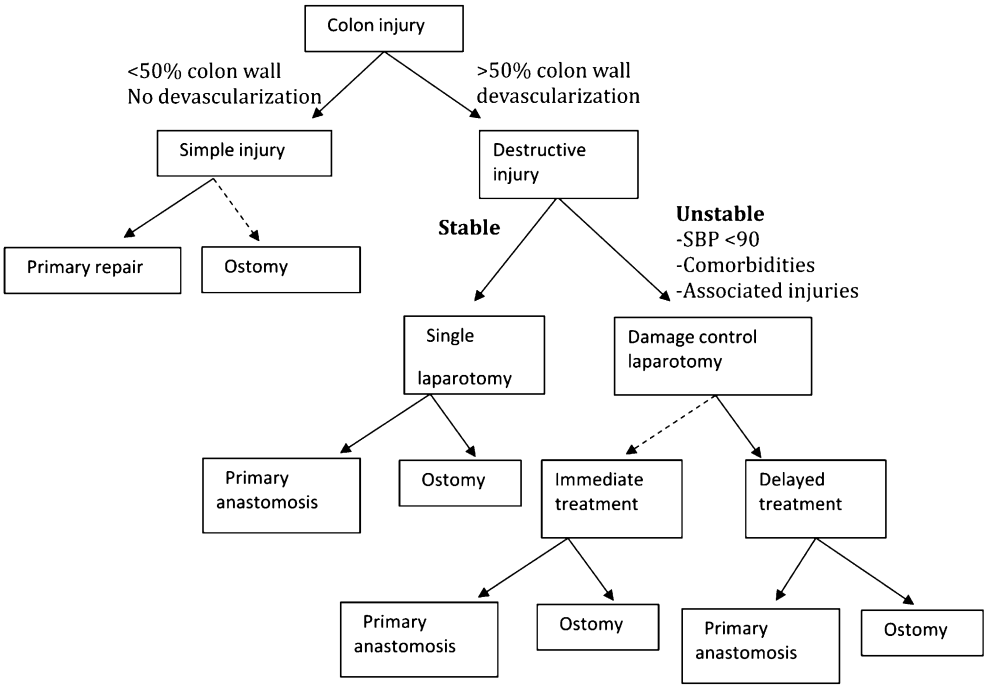


FIG. 1. Colon injury algorithm. Dotted lines indicate less favorable pathway.

Resection and Primary Anastomosis

The management of destructive injuries is more controversial. In 2001, the American Association for the Surgery of Trauma (AAST) sponsored a large (n = 297) multicenter, prospective, nonrandomized trial that sought to answer the question whether to divert or primarily anastomose colon injuries that required resection.[23] Patients chosen for diversion, when compared with patients who were anastomosed, had a higher PATI score (greater than 25), a larger number of left colon injuries, a higher incidence of delays getting to an operating room (greater than six hours), shock on admission, severe fecal contamination, and concurrent intra-abdominal injuries. There was a similar incidence of abdominal complications between the two groups (primary anastomosis at 22%, diversion at 27%), and the type of surgical management was not an independent risk factor for complications irrespective of factors in multivariate analysis. Based on these findings, the AAST recommended that colon injuries requiring resection should be managed with primary anastomosis regardless of risk factors to avoid the diminished quality of life and the need for additional operations for closure in patients managed with diversion.

Many advocate caution in mandating primary anastomosis in all patients. The AAST trial was not randomized, and several studies since then have shown significant complications with anastomosis in high-risk patients.[10, 18, 37] A prospective, observational study at Los Angeles County–University of Southern California performed in 1998 concluded that caution should be taken in high-risk patients with destructive colon injuries and that consideration should be given to fecal diversion resulting from the lack of Class I evidence.[18] Additionally, the Eastern Trauma Guidelines (1998) recommend that for destructive colon injuries with the presence of shock, significant associated injuries (PATI less than 25), significant underlying disease, or peritonitis, resection and fecal diversion should be performed.[19]

Anastomotic leaks are managed based on the clinical presentation. Some failures can be managed nonoperatively with a low-residue diet if the leak is contained and the patient is stable and not exhibiting systemic manifestations. If abscesses form, percutaneous drains can be placed. If the abscesses do not resolve, proximal diversion should be considered. In patients manifest with intra-abdominal sepsis, then management should be proximal diversion. The consequences of anastomotic failure have not been well documented. Vertrees et al.[10] noted that the consequences of anastomotic failure could have long-lasting consequences with higher risks at ostomy closure.

Fecal Diversion

Fecal diversion eliminates a suture line, and logic would assume decreased complications would result. This has not been the case and intra-abdominal abscess and septic complications are common. The 1998 Eastern Association for the Surgery of Trauma Guidelines recommend performing a diversion for destructive colon injuries with concurrent shock, multiple other abdominal injuries (PATI greater than 25), significant underlying morbidity, and peritonitis.[19] Management options for diversion after resecting the injured colon include loop ileostomy, end ileostomy, loop colostomy, end colostomy with a mucus fistula, and end colostomy with a Hartman's pouch. An advantage to performing a loop ostomy over an end colostomy is the ease of reversal, especially in a potentially hostile abdomen, because it avoids laparotomy. This makes loop ostomies the favored diversion by many trauma surgeons.[13] Some surgeons also advocate performing a primary repair with a proximal loop ostomy diversion in high-risk patients.[7] In this scenario, loop ileostomies are favored over colostomy because they are less odorous; they fit better in an appliance; they are technically easier to create; and they are less bulky. Complete diversion with a loop diversion can be achieved by stapling, suturing, or tying off the distal lumen of the loop if a total diversion is imperative.[13]

Advocates for primary anastomosis note the high complication rates associated with ostomy closure. Thirteen to 55 per cent complication rates have been reported in the literature compared with 12.5 per cent after colostomy reversals after rectal trauma.[7, 10, 40–43] Berne et al.[42] found that operative time greater than two hours, 150 mL of blood loss during the reversal, and a long delay until colostomy closure were risk factors for higher intraoperative difficulty attributed to a hostile abdomen, which was associated with increased morbidity. Complications include wound site infection, bleeding, intra-abdominal infections, anastomotic stricture, hernia, and pneumonia.

Although colostomy closure is usually performed three to six months after the initial trauma operation, this approach is widely debated. Some surgeons offer shorter interval closures, even during the same hospitalization for colostomies performed for colon injuries, not rectal injuries alone.[44, 45] Loop colostomy takedowns can be achieved under local anesthesia alone and may be attempted around the stoma site without opening the midline. A circumstomal skin incision is made with mobilization of the afferent and efferent limbs. An anastomosis between the two limbs is then achieved by hand-sewn or stapling techniques. In comparison, end colostomies with Hartman's

pouch require general anesthesia and may be attempted with an open midline incision or laparoscopic assistance.

Damage Control

Damage control surgery in severely injured patients is used to avoid the lethal triad of acidosis, hypothermia, and coagulopathy. The general goals of damage control laparotomy (DCL) in colon trauma are to control hemorrhage and prevent further contamination of the peritoneum. The patient's abdomen may be left open with a temporary abdominal closure in place and transferred to the intensive care unit for resuscitation. Waiting for 24 to 48 hours allows time for the evolution of the injuries and for improvement of the patient's physiology. The colon may be left in discontinuity for up to three days before significant bowel edema sets in, especially in light of colonic ileus and lack of forward peristalsis in severe injuries.

Delayed primary anastomosis has been successfully used both in military and civilian colonic injuries in the damage control setting in select patients before significant bowel edema sets in.[10, 44–46] Patients at high risk for anastomotic leaks after delayed anastomosis are those with left colon injuries and those who have received a large-volume resuscitation.[46] In military experience, 42 per cent of patients with colon injuries were managed with DCL.[10] All patients in this group underwent resection of the injured segment, and ostomy creation occurred in 63 per cent of these patients, including all those with left colon injuries. In that series, patients who had intestinal continuity re-established at the second operation had a lower rate of anastomotic leak than those primarily anastomosed in the first operation in a nondamage control setting (10 *vs* 27%; Table 1). Thus, re-establishing intestinal continuity after resection and resolution of physiologic derangements is a viable option of management compared with diversion.

Although DCL seems like a great equalizer of the risk factors that require caution before anastomosis including fluid status, coagulopathy, and other injuries, this has not resulted in improved outcomes. Table 1 notes several results of smaller studies noting the outcomes of anastomosis in the setting of damage control laparotomy compared with a single laparotomy.[10, 44–48] Most studies noted a higher leak rate in anastomosis performed as part of damage control laparotomy, although only one was statistically significant. These studies were all small and not randomized.

Two options for management of colon injury at DCL are reanastomosing the bowel and looking at the outcome at the future operation. The other option is to leave the ends stapled and in discontinuity and decide on anastomosis or ostomy at a future operation. Supporters for reanastomosis at the initial operation assume that the anastomosis could be easily found and repaired or converted to ostomy if there is a leak.[13] Others note that the anastomosis should be performed and "buried" deep in the abdomen or wrapped in omentum, and efforts to look at the anastomosis may lead to disruption.[44] Forming the anastomosis at the initial operation takes time, and the point of damage control surgery is to control all emergent issues and allow the patient to recover. Correcting anastomotic failure later may not be difficult as a result of shortening of the mesentery, bowel edema, and formation of a visceral block.[44]

The amount of time taken to close the abdomen can also influence the outcome of anastomosis. Burlew et al.[47] noted that the leak rate for anastomosis increased significantly with the delay in abdominal closure with increased leak rates noted beyond 5 days. Overall complications have been higher with an overall complication rate of 39 per cent compared with 14.3 per cent in the delayed colostomy group (although not statistically significant) and an anastomotic dehiscence rate of 12 per cent.[44]

Variations of Surgical Technique

Colon anastomosis can be accomplished by a handsewn or a stapled technique. There is abundant Class I evidence that stapling devices are equivalent in terms

TABLE 1. *Outcomes of Resection and Anastomosis in Damage Control Laparotomy (DCL) and Single Laparotomy (SL)*

		Damage Control Laparotomy				Single Laparotomy			
Study	Year	No.	Leaks (%)	Abscess (%)	Mortality (%)	No.	Leaks (%)	Abscess (%)	Mortality (%)
Ott et al.[46]	2011	44	12 (27%)*		4 (9%)	72	4 (6%)*		2 (3%)
Kashuk et al.[45]	2009	21	4 (16.6%)		0 (0%)	277	1 (0.3%)		0 (0%)
Weinberg et al.[44]	2008	33	4 (12.1%)	9 (27.3%)	4 (12.1%)	50	2 (4%)	7 (14%)	0 (0%)
Vertrees et al.[10]	2009	10	1 (10%)		0 (0%)	15	4 (27%)		1 (10%)
Burlew et al.[47]	2001	65	12 (18%)						
Miller et al.[48]	2007	11	0 (0%)	4 (36%)	5 (45%)	21	1 (5%)	5 (24%)	0 (0%)

Number of patients in study.
* Significant difference found in the study.
Blank spaces represent nonreported rates.

of outcomes when compared with hand-sewn anastomoses in elective colon resections.[49–51] A retrospective review of the type of colonic anastomotic method was performed in trauma patients requiring colon resections.[52] Researchers found that there was a higher rate of leaks in stapled anastomoses compared with hand-sewn anastomoses in their trauma population. This prompted the Western Trauma Association to perform a multicenter retrospective review in 2001 to see if stapled anastomoses were inferior to hand-sewn anastomoses in all colonic trauma patients. The Association found that the overall complication rates were higher in stapled *versus* hand-sewn anastomoses (20 *vs* 7%) and that there were significantly higher rates of leaks and intra-abdominal abscesses in patients with stapled anastomoses. They advised caution in deciding to staple bowel anastomoses in trauma patients because of the presence of bowel edema that is not present in elective colon surgery.[53] The AAST also looked at this question by analyzing the database from its 2001 prospective multicenter trial, specifically examining the type of anastomosis performed.[49] Of the 207 anastomoses performed, 128 were hand-sewn and 79 were stapled. They found no significant difference in complication rates in stapled (26.6%) *versus* hand-sewn (20.3%) anastomoses.

Single- *versus* double-layered anastomosis is also important to consider. Many studies of elective colonic surgery have shown that a running, single-layer anastomosis is at least as safe as a double-layer anastomosis.[50–52] A prospective randomized trial, which included some trauma patients, was performed, looking at single- *versus* double-layered anastomoses.[53] They found no difference in complication rates between the two groups; however, the surgery was faster by 10 minutes and patients were discharged 2 days earlier in the single-layer anastomosis group.[53]

Drain placement had been proposed for elective colon surgery cases, but the applicability to colon trauma is unknown.[54, 55] The purpose of a drain is to facilitate drainage of residual fluid not suctioned during the case as well as new fluid that accumulates during resuscitation. Routine drain placement is not typically practiced. Occasional drains can be placed, but they should be removed within 24 to 48 hours.[13]

Closure of the skin from the laparotomy incision should be opened or closed with a traumatic colon injury. A retrospective review of 223 patients with GSWs causing colon injuries found a 13 per cent rate of surgical site infection with no difference in infection rate if the skin was closed or left open.[56] A prospective, randomized trial was then performed, which found that wound infection rates decreased by half if the skin was left open to heal by primary repair (65 *vs* 36%).[57] Other risk factors for wound infection were colectomy and the presence of an intra-abdominal infection. Although not widely practiced, delayed primary closure of the skin can be performed. If a midline incision after a trauma laparotomy for a colon injury is closed primarily, it should be followed closely with a low threshold for opening the incision at the first sign of infection.

The duration of antibiotic therapy has been well studied.[56–58] Intra-abdominal infections occur in one of every four to six patients with colon injuries and is associated with high mortality.[23, 58] Adequate coverage for both aerobes (especially *Enterobacter* species, *Enterococcus* species, coagulase-negative *Staphylococcus*, *Streptococcus* species) and anaerobes (*Bacteroides fragilis*) should be provided. In general, a single broad-spectrum antibiotic will provide adequate coverage for nondestructive colon injuries (for example, second-generation cephalosporins or piperacillin).[56] However, in destructive colon injuries, the use of single antibiotic prophylaxis was an independent predictor for septic complications in the AAST Trial (31% in patients on single antibiotics *vs* 16% in patients who received combination antibiotics).[23] Therefore, combination antibiotics such as ampicillin/sulbactam are favored in destructive colon injuries. There is strong Class I evidence that shows that one does not need antibiotics for longer than 24 hours. Many surgeons provide only a single dose preoperatively. Even high-risk patients do not benefit from a longer course of antibiotics.[56, 57, 59] In fact, longer antibiotic regimens increase the incidence of resistant infections.[58]

War-injured

In civilian literature, there is a low rate of suture line leaks in patients who were managed with primary repair or resection and primary anastomosis (2 to 7%).[23, 40] However, 16 to 30 per cent of patients during the war in Iraq and Afghanistan who were managed initially with primary repair or anastomosis experienced leaks, which were subsequently managed with fecal diversion.[10, 12] Independent risk factors for anastomotic failures include hypotension or hemodynamic instability, advanced age, high abdominal trauma index, greater than 4 units PRBCs during the first 24 hours, abdominal compartment syndrome, prolonged intensive care unit stay, and a higher number of suture lines.[46] Increased volume of crystalloid, greater than 10.5 L within the first 72 hours, also appears to be a critical cutoff for anastomotic dehiscence in patients who have been resected and anastomosed.[36]

Complications

Complications after traumatic colon injuries are relatively high with an overall rate of 20 to 25 per cent.[6, 23]

Risk factors for higher morbidity after these injuries include multiple blood transfusions (greater than 4 units PRBCs), severe associated intra-abdominal injuries (high ISS or PATI grater than 25), significant fecal contamination, and management with fecal diversion.[6, 8] Infectious complications include surgical site infection, pneumonia, and intra-abdominal infections (7 to 27% incidence) with a higher incidence in patients managed with colostomy *versus* primary repair.[18, 49] Other reported complications include stricture, fistula (1 to 4% incidence), pulmonary embolus or deep venous thrombosis, acute respiratory distress syndrome, and hernia.[49]

Summary

The management of traumatic colon injury, typically classified as nondestructive or destructive, has varied dramatically over the past 200 years. Typically, signs of colonic injuries are detected on CT scan in stable patients or in the operating room in those who are hemodynamically compromised. All colonic injuries require surgical intervention. Nondestructive colon injuries should be managed with primary repair. The management of destructive injuries is more controversial, but it is believed that resection with anastomosis is the preferred management over fecal diversion. Additionally, the complication rates of colostomy closure may be as high as 55 per cent in patients with colon injuries, further supporting primary anastomosis whenever possible. Further study is needed to determine absolute contraindications to primary repair and primary anastomosis to avoid complications of ostomy closure. Damage control surgery is another strategy of management, although there is no consensus on how this strategy should be used to improve outcomes.

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