Destructive colon injuries requiring resection: Is colostomy ever indicated?

Delbrynth P. Mitchao, MD, Meghan R. Lewis, MD, Matt Strickland, MD, Elizabeth R. Benjamin, MD, PhD, Monica D. Wong, MS, *and* **Demetrios Demetriades, MD, PhD***, Los Angeles, California*

BACKGROUND: The management of destructive colon injuries requiring resection has shifted from mandatory diverting stoma to liberal use of primary anastomosis. Various risk criteria have been suggested for the selection of patients for primary anastomosis or ostomy. At our center, we have been practicing a policy of liberal primary anastomosis irrespective of risk factors. The purpose of this study was to evaluate the colon-related outcomes in patients managed with this policy.

METHODS: This retrospective study included all colon injuries requiring resection. Data collected included patient demographics, injury characteristics, blood transfusions, operative findings, operations performed, complications, and mortality.

RESULTS: A total of 287 colon injuries were identified, 101 of whom required resection, forming the study population. The majority (63.4%) were penetrating injuries. Furthermore, 16.8% were hypotensive on admission, 40.6% had moderate or severe fecal spillage, 35.6% received blood transfusion of >4 U, and 41.6% had Injury Severity Score of >15. At index operation, 88% were managed with primary anastomosis and 12% with colon discontinuity, and one patient had stoma. Damage-control laparotomy (DCL) with temporary abdominal closure was performed in 39.6% of patients. Of these patients with DCL, 67.5% underwent primary anastomosis, 30.0% were left with colon discontinuity, and 2.5% had stoma. Overall, after the definitive management of the colon, including those patients who were initially left in colon discontinuity, only six patients (5.9%) had a stoma. The incidence of anastomotic leaks in patients with primary anastomosis at the index operation was 8.0%, and there was no colon-related mortality. The incidence of colon anastomotic leaks in the 27 patients with DCL and primary anastomosis was 11.1%, and there was no colon-related mortality. Multivariate analysis evaluating possible risk factors identified discontinuity of the colon as independent risk factor for mortality.

CONCLUSION: Liberal primary anastomosis should be considered in almost all patients with destructive colon injuries requiring resection, irrespective of risk factors. (*J Trauma Acute Care Surg.* 2022;92: 1039–1046. Copyright © 2022 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic/Care Management; Level IV.

KEY WORDS: Destructive colon injuries; primary repair; stoma; outcomes.

Traumatic colon injuries are classified as nondestructive and destructive. Nondestructive colon injuries are those with involvement of ≤50% of the bowel wall and without devascularization, and they do not require resection. Destructive colon injuries, on the other hand, are those involving >50% of the colon's circumference or with segmental devascularization and require resection. Historically, a diverting stoma was thought to be the optimal management for all destructive colon injuries, especially in the presence of high-risk factors. Resection with primary anastomosis has increasingly gained acceptance, such that colostomies are now generally reserved only for high-risk patients. A survey among members of the American Association for the Surgery of Trauma (AAST) found that resection and anastomosis are the preferred procedures of 57% for colon laceration with >50% in diameter, 55% for a completely transected colon, 41% for blunt colon ruptures, and 37% for high-velocity gunshot wound.[1]

In the last decade, a more liberal policy of primary anastomosis has been adopted by many trauma surgeons, although there are still significant concerns regarding the role of primary anastomosis in high-risk patients. At our level 1 trauma center, there has been a policy of liberal anastomosis even in high-risk patients for many years. The purpose of this study was to review our practice and outcomes in this group of destructive colon injuries. Our hypothesis was that primary anastomosis can be performed liberally in patients with destructive colon injuries, irrespective of perceived "high-risk" conditions.

PATIENTS AND METHODS

This was a retrospective study at LAC+USC Medical Center, an academic level 1 trauma center in Los Angeles, California. The study was conducted using the LAC+USC Trauma Program registry and electronic medical records. Patients included in the trauma registry from June 2015 to December 2019 who met inclusion and exclusion criteria were enrolled, and further data were collected from the electronic medical record.

The study population included all adult patients (16 years or older) who sustained traumatic colon injuries and who were

Submitted: September 30, 2021, Revised: November 18, 2021, Accepted: December 13, 2021, Published online: January 25, 2022.

From the Division of Acute Care Surgery (D.P.M., M.R.L., M.D.W., D.D.), LAC+USC Medical Center, University of Southern California, Edmonton, Alberta, Canada; Trauma Surgery and General Surgery (M.S.), Royal Alexandra Hospital, Edmonton, Alberta, Canada; and Grady Memorial Hospital (E.R.B.), Emory University, Atlanta, Georgia.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text, and links to the digital files are provided in the HTML text of this article on the journal's Web site (www.jtrauma.com).

Address for reprints: Demetrios Demetriades, MD, PhD, Division of Acute Care Surgery, LAC+USC Medical Center, 1200 North State st, Los Angeles, CA 90033; email: demetria@usc.edu.

DOI: 10.1097/TA.0000000000003513

coded with an *International Classification of Diseases, Ninth Revision and Tenth Revision*, procedure codes indicating that the patient had undergone colon resection with anastomosis, creation of an ostomy, or been left in discontinuity. Patients who had only serosal injuries, had rectal involvement, expired within 24 hours of admission, were transferred to another institution, or went home against medical advice were excluded from analysis.

The decision for bowel discontinuity at index operation was surgeon dependent, with some surgeons never using discontinuity in damage-control procedures. Similarly, the method of anastomosis was surgeon's preference, with some surgeons always performing handsewn anastomosis or always stapled anastomosis.

The following data elements were collected: age, sex, body mass index, mechanism of injury, presence of shock at admission (systolic blood pressure [SBP], <90 mm Hg; heart rate, >120 beats per minute; Glasgow Coma Scale score, ≤8), Injury Severity Score, comorbidities (hypertension, diabetes mellitus, chronic renal disease), time from injury to operation, time from admission to skin incision, duration of procedure, presence of intraoperative hypotension (intraoperative SBP, <90 mm Hg), degree of fecal spillage as described in the operative report (minimal, moderate, or severe), site of colon injury (cecum, ascending, transverse and sigmoid), intraoperative blood loss, number of units of blood transfused in the first 4 and 24 hours, method of colon management (primary anastomosis, diversion, or discontinuity), handsewn or stapled anastomosis, location of suture line (ileocolonic, colocolonic, or both), and associated intra-abdominal and extra-abdominal injuries. The groups were also stratified according to whether they received damage-control laparotomy (DCL) with open abdomen.

The outcome variables included mortality, colonic anastomotic leak-related mortality, colon-related abdominal complications (anastomotic leak, colon necrosis, or anastomotic stricture), small bowel anastomotic leak, surgical site infection, enterocutaneous fistula, wound dehiscence, acute kidney injury, pneumonia, severe sepsis/septic shock, deep vein thrombosis, pulmonary embolism, intensive care unit admission, need for mechanical ventilation, hospital length of stay, and intensive care unit length of stay, and ventilator days. Management and follow-up data of those patients who had anastomotic leak were recorded.

Categorical variables were reported as percentages, while continuous variables were reported as medians with interquartile range (IQR). Univariate analysis was performed to identify the differences between DCL and non-DCL groups. Pearson's χ^2 test was used to compare the proportions of categorical variables. Mann-Whitney *U* test was used to compare the medians for continuous variables. Outcomes were compared according to the colonic management at the index procedure. In the logistic regression analysis, we forced in the variables that are perceived to be "risk factors" for adverse outcomes after primary anastomosis (mechanism, hypotension, severe fecal contamination, blood transfusions, side of colon injury, delayed of operation >6 hours from injury, discontinuity),to identify independent factors associated with mortality and colon anastomotic leaks.

Patient- and hospital-level potential confounding factors were adjusted with regression model for mortality and colon-related complications. The results are reported as odds ratios (ORs) and 95% confidence intervals (CIs). Correlation between variables was tested with multicollinearity analysis. The area under the curve with 95% CI was used to assess the accuracy of the test. Statistical significance was defined as $p < 0.005$. The statistical analysis was performed using SPSS for Mac version 23.0 (SPSS Inc., Chicago, IL). The study followed the equator network Strobe guidelines for cohort studies (Supplemental Digital Content, Supplementary Table 1, http://links.lww.com/TA/C333).

RESULTS

Epidemiological and Clinical Characteristics

During the 54-month study period, a total of 287 patients had colon injuries. One hundred fifty patients had nondestructive colon injuries, 9 had associated destructive rectal injuries, 3 left the hospital early against medical advice, 3 were transferred to another facility, and 21 died within 24 hours because of severe associated injuries. The remaining 101 patients met inclusion criteria and were included in the analysis (Fig. 1). The demographic and clinical characteristics of the study population are shown in Table 1.

Operative Findings

The median prehospital time was 30.0 minutes (IQR, 21.0–36.0 minutes). The median time of transport to the operating room was 55.0 minutes (IQR, 36.0–87.8 minutes). Fifty-one patients (50.5%) had an SBP of <90 mm Hg intraoperatively. The median duration of the index surgical procedure was 143.0 minutes (IQR, 114.5–188.0 minutes). On exploratory laparotomy, severe fecal spillage was described in 17.8% of patients, moderate on 22.8%, minimal on 25.7%, and none in 33.7%. The most common associated intra-abdominal organ injured was the small bowel (63.4% of patients), liver (20.8%), and stomach (14.9%). Details of the operative findings and blood transfusions are shown in Table 2.

Operative Management

Overall, 88 patients (87.1%) of the study population underwent resection and primary anastomosis at the initial operation (60 colocolostomy, 25 ileocolostomy, and 3 both procedures). One patient (1.0%) had a colostomy, and 12 (11.9%) were left in discontinuity. The only colostomy at the index operation was performed on a patient with DCL and was reversed the next day, by a different surgeon, with no anastomotic leak. Stapled anastomosis was favored over handsewn (73.9% vs. 26.1%).

In 61 patients (60.4%), the initial operation was definitive, and the abdomen was closed. All patients in this group had a primary colon anastomosis. In the remaining 40 patients (39.6%), a DCL with abdominal packing and temporary abdominal closure was performed. In this group of 40 patients with DCL, 27 (67.5%) underwent primary colon anastomosis, 12 (30%) were left in colon discontinuity, and 1 patient (2.5%) had a colostomy. Of the 12 cases with discontinuity, 7 had anastomosis and 3 had a stoma at the subsequent surgery, while 2 patients died before definitive procedure. The one colostomy case created at the initial operation was reversed to anastomosis the following day with no complications. Details of the surgical management of the study population are shown in Table 3.

Patients with DCL had higher intraoperative blood loss than patients without DCL (800.0 mL [462.5–2,500.0 mL] vs. 400.0 mL [200.0–1,000.0 mL], $p = 0.004$), received more

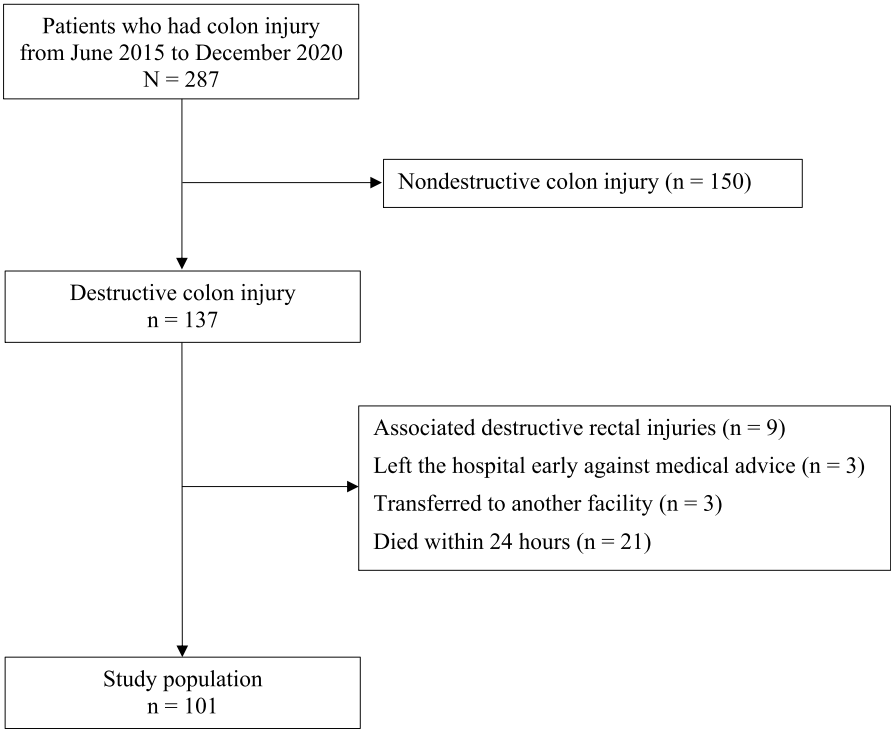

Figure 1. Study population.

packed red blood cells (PRBCs) transfusions in the first 4 hours (2.0 vs. 7.0 U, $p < 0.001$) or 24 hours (2.0 vs. 9.0 U, $p < 0.001$), and were more likely to receive >4 U of PRBCs in the first 4 hours (45.0% vs. 11.5%, $p = <0.001$) or within 24 hours (65.0% vs. 16.4%, $p = <0.001$).

TABLE 1. Demographic Characteristics of Patients Who Sustained Destructive Colon Injuries

	Total (N = 101)
Age, median, y	32 (23–42)
>65 y	5 (5.0%)
Male	83 (82.2%)
BMI, median (kg/m^2)	26.6 (24.3–31.4)
≥30 kg/m^2	33 (32.7%)
Mechanism of injury	
GSW	57 (56.4%)
Stab	7 (6.9%)
Blunt	37 (36.6%)
SBP <90 mm Hg	17 (16.8%)
Heart rate >120 bpm	16 (15.8%)
GCS score ≤8	12 (11.9%)
ISS >15	42 (41.6%)
Comorbidities	
Hypertension	6 (5.9%)
Diabetes mellitus	4 (4.0%)
Chronic renal disease	2 (2.0%)

bpm, Beats per minute; BMI, body mass index; GCS, Glasgow Coma Scale; GSW, gunshot wound; ISS, Injury Severity Score.

OUTCOMES

Mortality

There were eight deaths (7.9%) in the study population, none of them are due to colon-related complications. Of the eight deaths, three had resuscitative thoracotomy for cardiac arrest in the emergency department and died within 3 days of admission because of respiratory and renal failure, one had massive aspiration

TABLE 2. Intraoperative Details for Patients Who Sustained Destructive Colon Injuries

	Total (N = 101)
Injury to OR time, median (range), min	86.0 (57.5–116.5)
Surgery >6 h from injury time	4 (4.0%)
Duration of procedure, median (range), min	143.0 (114.5–188.0)
Intraoperative SBP <90 mm Hg	51 (50.5%)
None	34 (33.7%)
Minimal	26 (25.7%)
Moderate	23 (22.8)
Severe	18 (17.8%)
Bowel segment injured	
Cecum	14 (13.9%)
Ascending	16 (15.8%)
Transverse	33 (32.7%)
Descending	15 (14.9%)
Sigmoid	35 (34.7%)
Blood loss, median (range), cm^3	550 (200–1,200)
PRBC transfusion >4 U in 4 h	25 (24.8%)
PRBC transfusion >4 U in 24 h	36 (35.6%)

OR, operating room.

TABLE 3. Surgical Management of the Colon Patients With Destructive Colon Injuries

	Total (N = 101)	Non-DCL (n = 61)	DCL (n = 40)	*p*
Definitive management at index procedure	88 (87.1%)	61 (100.0%)	27 (67.5%)	<0.001
Primary anastomosis	88/88 (100.0%)	61/61 (100.0%)	27/27 (100.0%)	
Technique				
Stapled	65/88 (73.9%)	45/61 (73.8%)	20/27 (74.1%)	0.976
Handsewn	23/88 (26.1%)	16/61 (26.2%)	7/27 (25.9%)	
Type				
Ileocolonic only	25/88 (28.4%)	16/61 (26.2%)	9/27 (33.3%)	0.271
Colocolonic only	60/88 (68.2%)	44/61 (72.1%)	16/27 (59.3%)	
Both	3/88 (3.4%)	1/61 (1.6%)	2/27 (7.4%)	
Fecal diversion	0	0	0	—
Staged procedure	13 (12.9%)	0	13 (32.5%)	<0.001
Initial management				
Fecal diversion	1/13 (7.7%)	0	1/13(7.7%)	—
Discontinuity	12/13 (92.3%)	0	12/13 (92.3%)	—
Final management				
Primary anastomosis	9/13 (69.2%)	0	9/13 (69.2%)	—
Technique				
Stapled	4/9 (44.4%)	0	4/9 (44.4%)	—
Handsewn	5/9 (55.6%)		5/9 (55.6%)	
Type				
Ileocolonic only	2/9 (22.2%)	0	2/9 (22.2%)	—
Colocolonic only	7/9 (77.8%)	0	7/9 (77.8%)	
Both				
Fecal diversion	2/13 (15.4%)	0	2/13 (15.4%)	—
Discontinuity	2/13 (15.4%)	0	2/13 (15.4%)	—

pneumonia that led to respiratory failure, one had severe traumatic brain injury with complications from malignant intracranial hypertension, and three had small bowel leaks (two were duodenal and one was jejunal) leading to intra-abdominal sepsis and multiorgan failure. None of the three small bowel leak cases had concomitant colon suture line disruption; however, two of these cases involved sigmoid colon injuries left in discontinuity at the index procedure, which ended up with fecal diversion due of colon ischemia extending up to the descending colon. Details of all deaths are shown in Supplemental Digital Content (Supplementary Table 2, http://links.lww.com/TA/C333).

The mortality in the group of patients undergoing DCL was significantly higher than those not undergoing DCL (17.5% vs. 1.6% vs. $p = 0.004$). Multivariate analysis adjusting for mechanism, hypotension, fecal spillage, site of colon injury, delayed operative intervention, method of anastomosis, and blood transfusion >4 U in 24 hours identified discontinuity of the intestine as the most important risk factor for mortality (OR, 10.555; 95% CI, 1.200–92,854; $p = 0.034$). Blood transfusions >4 U and severe fecal spillage were associated with increased mortality, but they failed to reach statistical significance (Table 4).

Complications

Details of systemic, abdominal, and colon-related complications, overall and according to the method of colon management, are shown in Table 5.

The most common colon-related complication was surgical site infection at 28.4%, followed by intra-abdominal abscess at 9.9%, and anastomotic leak at 8.9%. All colon anastomotic leaks were colocolonic. Enterocutaneous fistulae occurred in three (3.0%) of the cases, with two patients been lost to follow-up and one leading to mortality after complications of a duodenojejunal anastomotic leak. In-hospital mortality was 7.8%. Details of outcomes according to surgical management of the colon are shown in Table 5.

In the group of 88 patients who underwent resection with anastomosis at the initial operation, the incidence of anastomotic leak was 8.0% (seven patients). On analysis of this subgroup of patients according to the site of their anastomosis, there were no leaks in the group of 25 patients with ileocolonic anastomosis and 7 leaks (11.1%) in the 63 patients with colocolonic anastomosis ($p = 0.082$) (Table 5). Of the seven anastomotic leaks,

TABLE 4. Multivariate Analysis for Independent Risk Factors for Mortality

	Adj *p*	OR	95% CI	
Blunt mechanism	0.202	5.013	0.422	59.519
Admission hypotension	0.267	0.185	0.009	3.647
Several fecal spillage	0.111	8.306	0.616	112.033
Left-sided injury	0.164	0.183	0.017	2.003
Surgery >6 h from injury time	0.999	0.000	0.000	—
Stapled anastomosis	0.776	0.721	0.077	6.802
Blood transfusion of >4 U in 24 h	0.096	8.217	0.690	97.797
Discontinuity on index procedure	0.034	10.555	1.200	92.854

Area under the receiver operating characteristic curve, 0.917 (95% CI, 0.838–0.995).
Adj, adjusted.

TABLE 5. Outcomes According to Surgical Management of the Colon

				Definitive Management of Patients in Discontinuity (n = 12)		
	Total (N = 101)	Primary Anastomosis at Initial Operation (n = 88)	Fecal Diversion (n = 1)	Primary Anastomosis (n = 8)	Fecal Diversion (n = 2)	No Definitive Management (n = 2)
Overall colon-related complications	12 (11.9%)	8 (9.1%)	0	3 (37.5%)	1 (50.0%)	0
Anastomotic leak	9 (8.9%)	7 (8.0%)	0	2 (25.0%)	0	0
Ileocolonic	0	0	0	0	0	0
Colocolonic	9 (8.9%)	7 (8.0%)	0	2 (25.0%)	0	0
Colon necrosis	7 (6.9%)	3 (3.4%)	0	3 (37.5%)	1 (50.0%)	0
Intra-abdominal abscess	10 (9.9%)	7 (8.0%)	0	3 (37.5%)	0	0
Small bowel anastomotic leak	10 (9.9%)	7 (8.0%)	0	2 (25.0%)	1 (50.0%)	0
Surgical site infection	29 (28.7%)	24 (27.3%)	0	5 (62.5%)	0	0
Enterocutaneous fistula	3 (3.0%)	2 (2.3%)	0	1 (12.5%)	0	0
Wound dehiscence	7 (6.9%)	6 (6.8%)	0	1 (12.5%)	0	0
Acute kidney injury	10 (9.9%)	7 (8.0%)	0	2 (25.0%)	1 (50.0%)	0
Pneumonia	6 (5.9%)	4 (4.5%)	0	2 (25.0%)	0	0
Severe sepsis/septic shock	9 (8.9%)	5 (5.7%)	0	3 (37.5%)	1 (50.0%)	0
Deep vein thrombosis	7 (6.9%)	6 (6.8%)	0	1 (12.5%)	0	0
Pulmonary embolism	2 (2.0%)	2 (2.3%)	0	0	0	0
HLOS, median (range), d	13.0 (7.5–25.0)	11.5 (7.0–22.0)	13.0	28.0 (16.6–47.0)	30.5 (19.0–)	4.0 (2.0–)
Requiring ICU monitoring	99 (98.0%)	86 (97.7%)	1 (100.0%)	8 (100.0%)	2 (100.0%)	2 (100.0%)
ICU LOS, median (range), d	5.0 (3.0–8.0)	4.0 (3.0–7.3)	13.0	12.0 (4.8–28.5)	24.0 (19.0–)	6.5 (2.0–)
Requiring mechanical ventilator	71 (70.3%)	58 (65.9%)	1 (100.0%)	8 (100.0%)	2 (100.0%)	2 (100.0%)
Ventilator days, median	3.0 (2.0–6.0)	3.0 (2.0–5.0)	4.0	8.0 (3.0–22.8)	19.0	3.5 (2.0–)
Mortality	8 (7.9%)	3 (3.4%)	0	2 (25.0%)	1 (50.0%)	2 (100.0%)
Colon anastomotic leak-related mortality	0	0	0	0	0	0

HLOS, hospital length of stay; ICU, intensive care unit; LOS, length of stay.

two underwent stoma creation for fecal diversion, two had debridement and repair of the leak, one had resection of ischemic colon and redo primary anastomosis, one was managed with percutaneous drainage, and one was successfully managed with antibiotics only. Details of all patients with anastomotic leaks are shown in Supplemental Digital Content (Supplementary Table 3, http://links.lww.com/TA/C333).

The incidence of colon anastomotic leak in the group of 61 patients with primary anastomosis and no DCL was 6.6% (4 patients). One of the patients developed colon ischemia and leak and required resection and colostomy, two patients developed a colocutaneous fistula which closed spontaneously, and one was treated with a percutaneous drain.

The incidence of colon anastomotic leaks in the group of 27 patients with DCL and primary anastomosis at the initial operation was 11.1% (3 patients). One of these patients developed colon ischemia and anastomotic leak and was successfully treated with resection and reanastomosis, one patient had a diverting colostomy, and one had the leak debrided and repaired, with uneventful recovery.

In the group of eight patients who had DCL with the colon in discontinuity at the initial operation and subsequently underwent anastomosis, there were two anastomotic leaks (25.0%). One was treated with fecal diversion, and one was successfully observed with only antibiotics. Injury characteristics and complications in patients with discontinuity at the index procedure are shown in Supplemental Digital Content (Supplementary Table 4, http://links.lww.com/TA/C333).

Overall, patients with DCL were significantly more likely to develop colon-related complications than those without DCL (25.0% vs. 6.6%, $p = 0.009$). Colon ischemia and necrosis (15.0% vs. 1.6%, $p = 0.010$) as well as intra-abdominal abscess (22.5% vs. 4.9%, $p = 0.038$) were also significantly higher in DCL cases. The incidence of colon anastomotic leaks was 12.5% vs. 6.6% ($p = 0.305$).

Multivariate analysis, which included mechanism, initial hypotension, severe fecal spillage, site of colon injury, operation >6 hours after injury, blood transfusions >4 U of PRBCs, and DCL, failed to identify any significant risk factors for anastomotic leak.

DISCUSSION

The management of colon injuries has changed significantly over the last two decades. By the 1990s and 2000s, primary repair without a diverting colostomy became the standard of care in all nondestructive colon injuries. Numerous well-designed studies showed the superiority of this approach in all penetrating colon injuries, including gunshot wounds.[2–5] However, the management of destructive colon injuries requiring resection, especially in the presence of perceived risk factors (hypotension, multiple blood transfusions, severe contamination, severe associated injuries, and delayed operation), is still a matter of controversy. With the popularization of abdominal damage-control operations, especially in cases with the colon left in discontinuity, the optimal management remains highly contentious. Many surgeons advocate resection

and discontinuity of the injured colon at the initial operation and definitive management (anastomosis or colostomy) at reoperation, after the patient is fully resuscitated. Some recommend colostomy at the time of DCL, and others opt for definitive anastomosis at the time of DCL.[6–9]

In penetrating destructive colon injury, the Eastern Association for the Surgery of Trauma (EAST) guidelines make a strong recommendation for resection and anastomosis rather than mandatory colostomy in low-risk patients (without signs of shock, significant hemorrhage, severe contamination, or delay to surgical intervention). In high-risk patients, the guidelines conditionally recommend primary anastomosis. In the setting of DCL, the guidelines conditionally recommend against mandatory colostomy. Instead, definitive repair or primary anastomosis at this initial operation, or resection with delayed anastomosis may be performed rather than colostomy.[10] Very often, the surgeon uses personal judgment rather than protocol. Interestingly, in an AAST survey, surgeons who manage fewer colon injuries were more likely to prefer colostomy.[1]

At our high-volume, level 1 trauma center, there has been a long-standing practice of liberal primary anastomosis in all destructive colon injuries, irrespective of proposed "risk factors." Stomas are very rarely created and are reserved for patients who are severely malnourished or have tenuous blood supply to the colon. In the current study, resection with primary anastomosis was performed in all 88 patients with no DCL. In the whole group of 101 patients, including 13 patients with DCL (12 of whom were left in colonic discontinuity at the initial operation), only 2 patients (2%) had a colostomy. This is the lowest colostomy rate reported in the literature. In a 2001 AAST multicenter study of 297 destructive colon injuries, 33.7% were treated with fecal diversion.[11–16]

In the present study, although primary anastomosis was performed much more frequently than previously published studies, the incidence of anastomotic leaks in patients undergoing primary anastomosis is very similar with studies, which used stricter criteria. Various "high-risk" conditions have been considered as possible contraindications for primary anastomosis in destructive colon injuries. These conditions include hypotension, multiple blood transfusions, fecal contamination, severe associated intra-abdominal injuries, delay of operation >6 hours, and damage-control operations.[12,17,18] However, these risk factors are associated with an increased risk of intra-abdominal sepsis, irrespective of the method of colon management. It has been shown in large studies that these risk factors are not associated with an increased risk of colon anastomotic leaks. In an AAST prospective study of 297 patients with penetrating destructive colon injuries requiring resection, these conditions were not found to be associated with an increased risk for anastomotic leaks. The study concluded that colon injuries that require resection may be managed with primary anastomosis, regardless of these risk factors.[13] The latest EAST Practice Management Guideline makes a conditional recommendation for primary anastomosis after destructive penetrating colon injury, in high-risk patients (delay >12 hours, shock, associated injury, transfusion >6 U of blood, contamination, or left side colon injuries).[10]

Anastomotic leak is the most feared complication following primary anastomosis. The prognosis of these leaks is usually good, and most patients can be safely managed nonoperatively, with percutaneous drainage and antibiotics. However, in some patients, the leak may result in severe abdominal sepsis, requiring reoperation. The reported overall mortality due to colon leak-related complications is low, at about 0.1%.[11,19] In the current study, there was no colon leak-related mortality in the nine anastomotic leaks. Four of these leaks were managed conservatively, three required reoperation and fecal diversion, one had debridement and repair of the leak, and one had resection and reanastomosis, Similar results were reported in the group of 13 patients with colon leaks in the AAST study in 2001.[13] Interestingly, the incidence of small bowel anastomotic leaks was similar to that in colon anastomosis.

The role of colon discontinuity in damage-control operations, although a common practice, remains a very controversial issue. There is some class III evidence that delayed primary anastomosis at 24 to 48 hours after the initial operation may be safe.[6–8] However, other studies reported that delayed colon anastomosis in damage-control operations is associated with a high incidence of anastomotic leaks, up to 27%.[9] The EAST Practice Management Guidelines "conditionally recommend against mandatory colostomy in patients with penetrating colon injury and DCL. Instead, based on clinical judgement, definitive repair or primary anastomosis at this initial operation, or delayed resection with anastomosis may be performed rather than colostomy."[10] There are concerns that discontinuity increases distention of the proximal colon, which might aggravate ischemia, especially in hypotensive patients requiring vasopressors. Clinical and experimental work showed significant bacteria and toxin translocation, within a few hours of complete bowel obstruction, even without bowel ischemia.[20–24] These findings provide some support of the view of avoiding bowel discontinuity in damage-control procedures.

In another retrospective study from 3 level 1 trauma centers, which included 167 trauma patients who required bowel resection and damage control, Talving et al.[25] found that discontinuity of the bowel was associated with a higher risk of bowel ischemia but not anastomotic leak than in patients with anastomosis. In a recent prospective AAST study of 244 patients with destructive gastrointestinal injuries requiring resection that underwent DCL, on multivariable analysis, discontinuity at the index operation was an independent predictor for anastomotic dehiscence (OR, 8.3; $p = 0.049$) and intra-abdominal abscess (OR, 2.8; $p = 0.021$).[26] In the current study, multivariate analysis identified colon discontinuity at the initial operation as the only significant independent risk factor for mortality but not anastomotic leak. This finding may certainly be the result of confounding variables but certainly warrants some careful consideration. It might be advisable to perform liberal definitive reconstruction of the colon at the initial operation, taking into account that a bowel anastomosis does not take more than a few minutes and the anastomosis can be reevaluated at the repeat laparotomy.

Crystalloids have been identified as a significant risk factor for anastomotic leak following colon resection after trauma. In an analysis of 92 patients, Schnüriger et al.[27] reported an overall incidence of anastomotic leaks of 13.0%. They identified ≥10.5 L of crystalloids given over the first 72 hours as independently associated with anastomotic breakdown, and a fivefold increased risk for colocolonic suture line failure.[27] It is possible that the new concept of damage-control resuscitation, which recommends limited use of crystalloids for resuscitation, may have contributed to the lower anastomotic leak of 8.0% in the present study, despite the much more liberal use of primary anastomosis.

Another possible risk factor for anastomotic leak that is debated is the anastomotic technique, handsewn or stapled. Earlier studies reported that stapled intestinal anastomoses in trauma were significantly more likely to breakdown than handsewn ones.[28] However, in a subsequent AAST prospective study of 207 patients with destructive colon injuries who underwent resection and anastomosis, the incidence of anastomotic leak was similar in the two groups, 6.3% in the stapled group and 7.8% in the handsewn group.[11] The present study confirmed that the method of anastomosis was not a significant factor for leak.

The results of the present and other recent studies support a liberal policy of primary anastomosis in destructive colon injuries requiring resection. A colostomy is very rarely needed, perhaps in selected patients with severe malnutrition or suspected bowel ischemia. In deciding on a management strategy for destructive colon injury, a surgeon must also consider the potential surgical, social, and emotional issues related to a stoma and the complications associated with the subsequent operation for colostomy closure.

Complications directly related to the ostomy construction include necrosis, retraction, prolapse, parastomal abscess, parastomal hernia, troublesome skin irritation, and poor anatomical site resulting in problems with the placement of the collection bag. In AAST prospective study of 297 patients who underwent colon resection for destructive colon injuries, the overall colon-related mortality was 1.3% (four deaths), and all deaths occurred in the diversion groups ($p = 0.01$).[13] In a series of 528 stomas created for trauma, the incidence of early complications was 22%, and incidence of late complications directly related to the stoma was 6%.[29] The morbidity of colostomy closure is also significant.[29,30] In a collective review of 809 colostomy closures in trauma patients, the overall incidence of colon-related complications was 13.1%.[19] In another study of 110 colostomy closures from Los Angeles, the overall incidence of local complications was 14.5%, including 2.7% rate of anastomotic leak.[30] Lastly, a significant number of trauma patients do not have ready access to medical care for colostomy takedown and, because of this, may be left with an ostomy for many years or even indefinitely.

The study has the inherent limitations of all retrospective studies. For example, the description of fecal spillage was subjective and the duration of intraoperative hypotension was not taken into account in the analysis. Finally, other important confounding variables influencing outcomes may have been missed. Only a prospective, randomized multicenter study can provide a definitive answer. However, in view of the current available evidence, ethically, it is unlikely that such a study will ever be approved and performed.

CONCLUSION

Liberal primary anastomosis should be considered in almost all patients with destructive colon injuries requiring resection. The traditional risk factors are not contraindications for primary anastomosis.

AUTHORSHIP

D.P.M. contributed in the data collection, data analysis, data interpretation, and writing. M.R.L. contributed in the study design, data analysis, data interpretation, writing, and critical revision. M.S. contributed in the data collection, data analysis, data interpretation, and critical revision. E.R.B. contributed in the study design, data analysis, data interpretation, writing, and critical revision. M.D.W. contributed in the data collection and data analysis. D.D. contributed in the study design, literature search, data analysis, data interpretation, and writing.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Eshraghi N, Mullins RJ, Mayberry JC, Brand DM, Crass RA, Trunkey DD. Surveyed opinion of American trauma surgeons in management of colon injuries. *J Trauma*. 1998;44(1):93–97.
2. Chappuis CW, Frey DJ, Dietzen CD, Panetta TP, Buechter KJ, Cohn I Jr. Management of penetrating colon injuries. A prospective randomized trial. *Ann Surg*. 1991;213(5):492–497.
3. Demetriades D, Charalambides D, Pantanowitz D. Gunshot wounds of the colon: role of primary repair. *Ann R Coll Surg Engl*. 1992;74(6):381–384.
4. Sasaki LS, Allaben RD, Golwala R, Mittal VK. Primary repair of colon injuries: a prospective randomized study. *J Trauma*. 1995;39(5):895–901.
5. Gonzalez RP, Falimirski ME, Holevar MR. Further evaluation of colostomy in penetrating colon injury. *Am Surg*. 2000;66(4):342–346.
6. Ordoñez CA, Pino LF, Badiel M, Sánchez AI, Loaiza J, Ballestas L, Puyana JC. Safety of performing a delayed anastomosis during damage control laparotomy in patients with destructive colon injuries. *J Trauma*. 2011;71(6):1512–1517.
7. Burlew CC, Moore EE, Cuschieri J, Jurkovich GJ, Codner P, Crowell K, Nirula R, Haan J, Rowell SE, Kato CM, et al. Sew it up! A Western Trauma Association multi-institutional study of enteric injury management in the postinjury open abdomen. *J Trauma*. 2011;70(2):273–277.
8. Kashuk JL, Cothren CC, Moore EE, Johnson JL, Biffl WL, Barnett CC. Primary repair of civilian colon injuries is safe in the damage control scenario. *Surgery*. 2009;146(4):663–668.
9. Ott MM, Norris PR, Diaz JJ, Collier BR, Jenkins JM, Gunter OL, Morris JA Jr. Colon anastomosis after damage control laparotomy: recommendations from 174 trauma colectomies. *J Trauma*. 2011;70(3):595–602.
10. Cullinane DC, Jawa RS, Como JJ, Moore AE, Morris DS, Cheriyan J, Guillamondegui OD, Goldberg SR, Petrey L, Schaefer GP, et al. Management of penetrating intraperitoneal colon injuries: a meta-analysis and practice management guideline from the Eastern Association for the Surgery of Trauma. *J Trauma Acute Care Surg*. 2019;86(3):505–515.
11. Demetriades D, Murray JA, Chan LS, Ordonez C, Bowley D, Nagy KK, Cornwell EE 3rd, Velmahos GC, Munoz N, Hatzitheofilou C, et al. Handsewn versus stapled anastomosis in penetrating colon injuries requiring resection: a multicenter study. *J Trauma*. 2002;52(1):117–121.
12. Murray JA, Demetriades D, Colson M, Song Z, Velmahos GC, Cornwell EE 3rd, Asensio JA, Belzberg H, Berne TV. Colonic resection in trauma: colostomy versus anastomosis. *J Trauma*. 1999;46(2):250–254.
13. Demetriades D, Murray JA, Chan L, Ordoñez C, Bowley D, Nagy KK, Cornwell EE 3rd, Velmahos GC, Muñoz N, Hatzitheofilou C, et al, Committee on Multicenter Clinical Trials American Association for the Surgery of Trauma. Penetrating colon injuries requiring resection: diversion or primary anastomosis? An AAST prospective multicenter study. *J Trauma*. 2001;50(5):765–775.
14. Miller PR, Fabian TC, Croce MA, Magnotti LJ, Elizabeth Pritchard F, Minard G, Stewart RM. Improving outcomes following penetrating colon wounds: application of a clinical pathway. *Ann Surg*. 2002;235(6):775–781.
15. Sharpe JP, Magnotti LJ, Weinberg JA, Parks NA, Maish GO, Shahan CP, Fabian TC, Croce MA. Adherence to a simplified management algorithm reduces morbidity and mortality after penetrating colon injuries: a 15-year experience. *J Am Coll Surg*. 2012;214(4):591–597 discussion 597-8.
16. Cheng V, Schellenberg M, Inaba K, Matsushima K, Warriner Z, Trust MD, Lam L, Demetriades D. Contemporary trends and outcomes of blunt traumatic colon injuries requiring resection. *J Surg Res*. 2020;247:251–257.
17. Cornwell EE 3rd, Velmahos GC, Berne TV, Murray JA, Chahwan S, Asensio J, Demetriades D. The fate of colonic suture lines in high-risk trauma patients: a prospective analysis. *J Am Coll Surg*. 1998;187(1):58–63.
18. Stewart RM, Fabian TC, Croce MA, Pritchard FE, Minard G, Kudsk KA. Is resection with primary anastomosis following destructive colon wounds always safe? *Am J Surg*. 1994;168(4):316–319.
19. Curran TJ, Borzotta AP. Complications of primary repair of colon injury: literature review of 2,964 cases. *Am J Surg*. 1999;177(1):42–47.

20. Zanoni FL, Benabou S, Greco KV, Moreno AC, Cruz JW, Filgueira FP, Martinez MB, Figueiredo LF, Silva MR, Sannomiya P. Mesenteric microcirculatory dysfunctions and translocation of indigenous bacteria in a rat model of strangulated small bowel obstruction. *Clinics (Sao Paulo)*. 2009;64(9):911–919.
21. Aldemir M, Kökoğlu OF, Geyik MF, Büyükbayram H. Effects of octreotide acetate and Saccharomyces boulardii on bacterial translocation in an experimental intestinal loop obstruction model of rats. *Tohoku J Exp Med*. 2002;198(1):1–9.
22. Enochsson L, Nylander G, Ohman U. Effects of intraluminal pressure on regional blood flow in obstructed and unobstructed small intestines in the rat. *Am J Surg*. 1982;144(5):558–561.
23. Deitch EA, Bridges WM, Ma JW, Ma L, Berg RD, Specian RD. Obstructed intestine as a reservoir for systemic infection. *Am J Surg*. 1990;159(4):394–401.
24. Ji W, Ding W, Liu X, Kao X, Xu X, Li N, Li J. Intraintestinal drainage as a damage control surgery adjunct in a hypothermic traumatic shock swine model with multiple bowel perforations. *J Surg Res*. 2014;192(1):170–176.
25. Talving P, Chouliaras K, Eastman A, Lauerman M, Teixeira PG, DuBose J, Minei J, Scalea T, Demetriades D. Discontinuity of the bowel following damage control operation revisited: a multi-institutional study. *World J Surg*. 2017;41(1):146–151.
26. Benjamin E, Cremonini C, Lauerman M, Bradley N, Pedersen C, Skarupa DJ, Turay D, Berne JD, Dhir T, Young J, et al. Bowel discontinuity during damage control laparotomy is associated with increased risk of anastomotic dehiscence: results of an AAST prospective multi-institutional study. In: 79th Annual Meeting of AAST and Clinical Congress of Acute Care Surgery; September 8–12, 2019; Waikoloa, HI.
27. Schnüriger B, Inaba K, Wu T, Eberle BM, Belzberg H, Demetriades D. Crystalloids after primary colon resection and anastomosis at initial trauma laparotomy: excessive volumes are associated with anastomotic leakage. *J Trauma*. 2011;70(3):603–610.
28. Brundage SI, Jurkovich GJ, Grossman DC, Tong WC, Mack CD, Maier RV. Stapled versus sutured gastrointestinal anastomoses in the trauma patient. *J Trauma*. 1999;47(3):500–507; discussion 507–8.
29. Park JJ, Del Pino A, Orsay CP, Nelson RL, Pearl RK, Cintron JR, Abcarian H. Stoma complications: the Cook County Hospital experience. *Dis Colon Rectum*. 1999;42(12):1575–1580.
30. Demetriades D, Pezikis A, Melissas J, Parekh D, Pickles G. Factors influencing the morbidity of colostomy closure. *Am J Surg*. 1988;155(4):594–596.