

Analysis of over 2 decades of colon injuries identifies optimal method of diversion: Does an end justify the means?

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INTRODUCTION:	Conflicting evidence exists regarding the definitive management of destructive colon injuries. Although diversion with an end ostomy can theoretically decrease initial complications, it mandates a more extensive reversal procedure. Conversely, anastomosis with proximal loop ostomy diversion, while simplifying the reversal, increases the number of suture lines and potential initial morbidity. Thus, the purpose of this study was to evaluate the impact of diversion technique on morbidity and mortality in patients with destructive colon injuries.
METHODS:	Consecutive patients with destructive colon injuries managed with diversion from 1996 to 2016 were stratified by demographics, severity of shock and injury, operative management, and timing of reversal. Outcomes, including ostomy complications (obstruction, ischemia, readmission) and reversal complications (obstruction, abscess, suture line failure, fascial dehiscence), were compared between patients managed with a loop versus end colostomy. Patients with rectal injuries and who died within 24 hours were excluded.
RESULTS:	A total of 115 patients were identified: 80 with end colostomy and 35 with loop ostomy. Ostomy complications occurred in 22 patients (19%), and 11 patients (10%) suffered reversal complications. There was no difference in ostomy-related (2.9% vs. 3.8%, $p = 0.99$) mortality. For patients without a planned ventral hernia (PVH), there was no difference in ostomy complications between patients managed with a loop versus end colostomy (12% vs. 18%, $p = 0.72$). However, patients managed with a loop ostomy had a shorter reversal operative time (95 vs. 245 minutes, $p = 0.002$) and reversal length of stay (6 vs. 10, $p = 0.03$) with fewer reversal complications (0% vs. 36%, $p = 0.02$). For patients with a PVH, there was no difference in outcomes between patients managed with a loop versus end colostomy.
CONCLUSION:	For patients without PVH, anastomosis with proximal loop ostomy reduced reversal-related complications, operative time, LOS, and hospital charges without compromising initial morbidity. Therefore, loop ostomy should be the preferred method of diversion, if required, following destructive colon injury. (<i>J Trauma Acute Care Surg.</i> 2019;86: 214–219. Copyright © 2018 American Association for the Surgery of Trauma.)
LEVEL OF EVIDENCE:	Therapeutic, level IV.
KEY WORDS:	Destructive colon injuries; colon trauma; loop ostomy; end ostomy; ostomy reversal.

Despite continued advancements in the operative management of colon injuries, optimal management of destructive colon wounds requiring resection remains controversial. Although specific risk factors for suture line failure after resection and anastomosis remain inconsistent between institutions,^{1,2} selective use of diversion for destructive colon injuries results in decreased morbidity. In fact, previous work at our institution helped develop a defined management algorithm (Fig. 1) to identify clinical criteria for diversion, reducing both colon-related morbidity and mortality since its implementation over 20 years ago.^{3–7}

The optimal method of diversion, however, is not well described in the literature. Diversion with an end ostomy can theoretically decrease initial complications, but it mandates a more extensive reversal procedure. Conversely, anastomosis with proximal loop ostomy diversion, while simplifying the reversal, increases the number of suture lines and potential initial morbidity.

For those purporting diversion, there are little, if any, data comparing end colostomy to anastomosis plus proximal diversion. In our institution, operative decisions (resection plus anastomosis vs. diversion) for these colon injuries are based on the previously defined management algorithm. The purpose of this study was to evaluate the impact of operative technique on morbidity and mortality in patients with destructive colon injuries requiring diversion. We hypothesized that outcomes would be equivalent between those

patients managed with anastomosis with proximal loop ostomy and those who underwent an end colostomy.

METHODS

Identification of Patients

Following approval from the Institutional Review Board at the University of Tennessee Health Science Center, consecutive adult patients sustaining destructive colon injuries managed with diversion over a 21-year period were identified from the trauma registry of the Presley Regional Trauma Center in Memphis, Tennessee. The charts of these patients were reviewed for data regarding patient characteristics, mechanism and severity of injury, severity of shock, operative management, location of injury and outcomes. These data were merged with patient data from the trauma registry (NTRACS version 3.5, Digital Innovations) to compile the database for this study. Patients who died within 24 hours and those with rectal injuries were excluded from the study.

Management

Patients with colon injuries were managed with our existing institutional protocol (Fig. 1). All patients with nondestructive injuries underwent primary repair. Patients with destructive wounds but no comorbidities or preoperative or intraoperative transfusion requirements of less than 6 units of packed red blood cells (PRBCs) were classified as low risk and underwent resection plus anastomosis. Otherwise, patients with destructive wounds and significant comorbidities or preoperative or intraoperative transfusion requirements of more than 6 units of PRBCs were classified as high risk and underwent diversion.

Patients who met the criteria for diversion were then managed with either an anastomosis with proximal loop ostomy diversion or with an end ostomy. The type of ostomy chosen was not based on an existing protocol and was left to the discretion of the operating surgeon at the time of operation. For those patients

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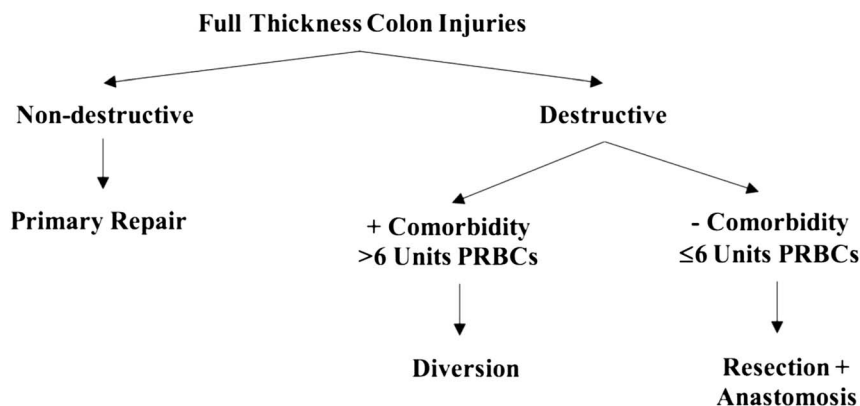


Figure 1. Management algorithm for destructive colon injuries.

who required a staged operation with abbreviated laparotomy and subsequent take-back operation, the ostomy was performed at the initial take back and was performed within 48 hours of admission.

Outcomes

Primary outcomes included ostomy complications and reversal complications. Ostomy complications were defined as obstruction, ischemia, and readmission to the hospital for ostomy-related morbidity (e.g., dehydration or electrolyte abnormalities). Reversal complications included obstruction, abscess, suture line failure, and fascial dehiscence. Secondary outcomes included ostomy-related and reversal-related mortality, initial and reversal hospital length of stay, reversal operative time, and hospital charges (calculated from length of stay and operative time).

Comparisons

Characteristics and outcomes were compared between patients who received an anastomosis with proximal loop ostomy and those who underwent end ostomy. A subgroup analysis was performed to make the same comparison amongst patients with and without a planned ventral hernia (PVH). Statistical analyses were performed using a Student *t* test, Wilcoxon rank sum test, and χ^2 or Fisher's exact test where appropriate. The Kolmogorov-Smirnov test for normality was performed on all continuous variables; those that were normally distributed are presented with means and standard deviations, and those that were not normally distributed are presented as medians and interquartile ranges. All statistical analysis was performed using SAS 9.4 (SAS Institute, Cary, NC). A *p* value of <0.05 was considered statistically significant.

RESULTS

Study Population

During the 21-year period (January 1996 to December 2016), 115 patients suffered destructive colon injuries requiring diversion. Of these, 100 patients (87%) were male and 15 (13%) were female. A majority (73%) suffered penetrating mechanisms. Mean age and Injury Severity Score were 36 years and 24, respectively. The majority of injuries were located in the transverse (27%) and sigmoid (26%) colon, followed by the ascending colon (17%), descending colon (15%), splenic flexure

(9%), and hepatic flexure (6%). Mean initial hospital length of stay was 38 days, and initial overall mortality was 3.5%.

Of the 115 patients, 35 (30%) received an anastomosis and proximal loop ostomy and 80 (70%) received an end ostomy. Forty-nine percent of the diversions were colostomies, and 51% were ileostomies. Forty-seven patients required a PVH. Ostomy complications occurred in 22 patients (19%), and 11 patients (10%) suffered reversal complications. Seventy-one patients (62%) underwent ostomy reversal. Mean time to reversal was 10 months. Mean hospital length of stay for ostomy reversal was 11 days. Reversal-related mortality was 0%.

Comparison: Loop Versus End Ostomy

Table 1 demonstrates a comparison between those patients who underwent an anastomosis with proximal loop ostomy and those who received an end ostomy after destructive colon injury. The two groups were similar with respect to age, sex, injury mechanism, severity of initial shock (as measured by admission systolic blood pressure, base excess, intraoperative PRBCs), and severity of injury (as measured by Injury Severity Score and Abdominal Abbreviated Injury Scale). For the patients with a penetrating mechanism, there was no difference in the two groups with respect to the Penetrating Abdominal Trauma Index (34 vs. 32, $p = 0.64$). Furthermore, there was no difference between the two groups with respect to requiring a PVH (51% vs. 36%, $p = 0.13$).

Patients who underwent anastomosis with proximal loop ostomy were also similar to those patients who received an end ostomy with respect to initial hospital length of stay, ostomy complications, and mortality (Table 1). However, those patients with an anastomosis with proximal loop ostomy were more likely to undergo ostomy reversal (77% vs. 56%, $p = 0.04$) compared with patients managed with an end ostomy. Furthermore, for those patients who underwent ostomy reversal, patients with an anastomosis with proximal loop ostomy experienced shorter operative times (133 vs. 313 minutes, $p = 0.007$) with fewer reversal complications (4% vs. 22%, $p = 0.04$). The two groups were similar with respect to time to reversal and reversal hospital length of stay.

Comparison: Patients Without PVH

Sixty-eight patients had diversion of their destructive colon injuries without a subsequent PVH. Of these, 17 (25%)

TABLE 1. Comparison of Patient Characteristics and Outcomes Between Patients Who Underwent Loop Ostomy and Those Who Received End Ostomy

	Loop Ostomy	End Ostomy	<i>p</i>
n	35	80	
Age	37 (15)	36 (16)	0.83
Male, %	91	85	0.55
Blunt injury, %	26	28	0.99
Systolic blood pressure	120 (29)	112 (42)	0.25
Base excess	-4.2 (7.8)	-7 (7.5)	0.10
Injury severity score	24 (10-34)	23 (16-32)	0.95
Abdominal abbreviated injury scale	4 (3-4)	4 (3-4)	0.83
Location of injury, %			0.29
Ascending	23	14	
Hepatic flexure	3	7	
Transverse	20	30	
Splenic flexure	14	6	
Descending	20	14	
Sigmoid	20	29	
Staged procedure, %	83	71	0.25
Intraoperative RBC transfusion, units	10 (5-14)	10 (4-14)	0.58
PVH, %	51	36	0.13
Ostomy-related complications, %	20	19	0.99
Initial hospital days	32 (15-49)	29 (18-46)	0.66
Mortality, %	2.9	3.8	0.99
Underwent reversal, %	77	56	0.04
Time to reversal, mo	9 (4.5-12)	9 (6-13)	0.59
Operative time for reversal, min	133 (90-266)	313 (240-418)	0.007
Reversal complications, %	4	22	0.04
Reversal hospital days	9 (5-10)	9 (6-12)	0.22

All continuous variables are listed as means with standard deviation in parentheses or medians with interquartile ranges in parentheses.

RBC, red blood cells.

underwent an anastomosis with proximal loop ostomy and 51 (75%) received an end ostomy. There were no significant differences between the two groups in terms of age, sex, injury mechanism, severity of initial shock, and severity of injury (Table 2). Furthermore, the groups were similar with respect to initial hospital length of stay, ostomy complications, and mortality. Interestingly, in this subgroup of patients without PVH, patients with an anastomosis with proximal loop ostomy were not more likely to undergo ostomy reversal (71% vs. 55%, $p = 0.39$) compared with patients managed with an end ostomy. However, patients who underwent reversal of their loop ostomy demonstrated much shorter reversal operative times (95 vs. 245 minutes, $p = 0.002$), fewer reversal complications (0% vs. 36%, $p = 0.02$), and shorter reversal hospital length of stay (6 vs. 10 days, $p = 0.03$) when compared with those who underwent end ostomy reversal. Accounting for all these differences, use of an anastomosis with proximal loop ostomy in patients without a PVH reduced hospital charges by US \$763,000.

Comparison: Patients With PVH

Of the 47 patients who had diversion of their destructive colon injuries with a subsequent PVH, 18 (38%) were managed

with an anastomosis with proximal loop ostomy and 29 (62%) received an end ostomy. There were no significant differences between the two groups in terms of age, sex, injury mechanism, and severity of injury (Table 3). Patients managed with an anastomosis with proximal loop ostomy did have a higher admission base excess (-3.4 vs. -9, $p = 0.04$) compared with those patients managed with an end ostomy. Nevertheless, the groups were similar with respect to initial hospital length of stay, ostomy complications, and mortality. There was also no difference in ostomy reversal operative time, reversal length of stay, or reversal complications between patients with a PVH managed with an anastomosis with proximal loop ostomy and those with an end ostomy.

DISCUSSION

In the current study, we sought to evaluate the impact of operative technique on morbidity and mortality in patients with destructive colon injuries requiring diversion and hypothesized that outcomes would be equivalent for patients managed with anastomosis with proximal loop ostomy and those who underwent end colostomy. For patients without a PVH, an anastomosis with proximal loop ostomy reduced reversal-related complications, operative time, length of stay, and hospital charges without compromising initial morbidity. For patients with PVH, anastomosis with proximal loop ostomy provided no benefit over end colostomy.

Over the past century, changes in the operative management of colon injuries have produced dramatic improvements in both morbidity and mortality. Before the 20th century, colon wounds were almost uniformly fatal. Patients that did not succumb to their primary injuries ultimately died from secondary infection and sepsis following expectant management.^{8,9} During

TABLE 2. Comparison of Patient Characteristics and Outcomes Between Patients Without PVH Who Underwent Loop Ostomy and Those Who Received End Ostomy

	Loop Ostomy	End Ostomy	<i>p</i>
n	17	51	
Age	35 (16)	36 (17)	0.81
Male, %	88	84	0.99
Blunt injury, %	24	33	0.55
Systolic blood pressure	120 (32)	118 (39)	0.84
Base excess	-5.3 (5.8)	-5.7 (7.0)	0.84
Injury severity score	16 (10-29)	24 (16-34)	0.35
Abdominal abbreviated injury scale	4 (3-4)	4 (3-4)	0.65
Intraoperative RBC transfusion, units	8 (4-11)	8 (4-13)	0.66
Staged procedure, %	65	59	0.78
Ostomy-related complications, %	12	18	0.72
Initial hospital days	15 (13-27)	21 (12-40)	0.31
Mortality, %	0	4	0.99
Underwent reversal, %	71	55	0.39
Time to reversal, mo	5 (4-10)	7 (6-10)	0.14
Operative time for reversal, min	95 (77-120)	245 (238-313)	0.002
Reversal complications, %	0	36	0.02
Reversal hospital days	6 (4-8)	10 (6-14)	0.03

All continuous variables are listed as means with standard deviation in parentheses or medians with interquartile ranges in parentheses.

RBC, red blood cells.

TABLE 3. Comparison of Patient Characteristics and Outcomes Between Patients With PVH Who Underwent Loop Ostomy and Those Who Received End Ostomy

	Loop Ostomy	End Ostomy	<i>p</i>
n	18	29	
Age	37 (15)	39 (13)	0.49
Male, %	94	86	0.64
Blunt injury, %	28	17	0.47
Systolic blood pressure	120 (27)	101 (46)	0.09
Base excess	-3.4 (9.1)	-9 (8.1)	0.04
Injury severity score	27 (18–41)	19 (16–32)	0.31
Abdominal abbreviated injury scale	3 (3–5)	4 (3–5)	0.39
Intraoperative RBC transfusion, units	9 (7–17)	10 (7–19)	0.71
Ostomy-related complications, %	28	21	0.73
Initial hospital days	43 (32–59)	38 (29–77)	0.63
Mortality, %	5.6	3.5	0.99
Underwent reversal, %	82	59	0.12
Time to reversal, mo	10 (8.5–16)	10 (8–15)	0.92
Operative time for reversal, min	316 (244–534)	403 (335–427)	0.68
Reversal complications, %	7	0	0.45
Reversal hospital days	10 (9–12)	9 (9–12)	0.59
Ostomy or reversal complication, %	33	21	0.49

All continuous variables are listed as means with standard deviation in parentheses or medians with interquartile ranges in parentheses.

RBC, red blood cells.

World War I, mortality following colon injuries fell to 60% to 75% following a paradigm shift in management: nonoperative care in the initial stages to exploration and diversion by the end of the war.¹⁰ With improvements in operative management including resuscitation, antibiotics, triage, and mandatory diversion of all colon injuries, mortality rates secondary to colon wounds fell to as low as 22% following World War II.^{11–14} Post-war investigations by civilian trauma surgeons soon found that obligatory ostomy was unnecessary in most patients, and a more selective use of diversion for destructive colon injuries could result in low morbidity.^{3,14,15}

The current literature supports the use of diversion following resection of colon wounds in select cases. However, the optimal method for diversion of these injuries remains controversial. Pachter et al.¹⁶ were one of the first groups to evaluate the morbidity and financial impact of colostomy closure in trauma patients. In their review of 87 patients who had undergone colostomy closure following trauma, they noted a mean hospital length of stay of 15 days and a 25% morbidity rate for the entire study population. From their results, they noted the development of a postreversal complication, such as a small bowel obstruction or intra-abdominal abscess, increased hospital stay, and cost by an estimated 50%. However, the authors did not evaluate the impact of diversion technique on outcomes.¹⁶

Similar to Pachter et al.,¹⁶ Berne et al.¹⁷ performed a review of 40 patients who had undergone colostomy closure after trauma. The authors found an overall complication rate of 30%. In a subgroup analysis, they also found that morbidity following reversal of an end ostomy was over two-fold greater than that for loop ostomy reversal (21% vs. 50%, $p = 0.13$). In 2003, Bulger et al.¹⁸ evaluated 60 patients who had undergone ostomy

reversal following penetrating trauma. The authors found an overall complication rate of 17%. Unlike Berne et al.,¹⁷ they failed to demonstrate increased morbidity following end ostomy reversal compared with loop ostomy reversal. However, Bulger et al.¹⁸ suggested that there was a trend toward a higher anastomotic stricture rate with loop ostomy closure (3/13, 23%), compared with a Hartman's pouch (1/38, 2.8%) or mucous fistula (1/11, 9%), $p = 0.08$.

In 2015, Bruns et al.¹⁹ performed the first multi-institutional study dedicated to examining the impact of loop ostomy creation versus end ostomy in trauma patients. The authors examined 218 trauma patients over 6 years who underwent reversal of their ostomy. Of these, 58 were initially managed with a loop ostomy and 160 were initially managed with an end ostomy. Similar to the current study, Bruns et al.¹⁹ found that patients with an end ostomy had a longer reversal hospital length of stay (8.4 vs. 5.5, $p < 0.001$) with a higher reversal morbidity (51% vs. 30%, $p = 0.005$). The authors also concluded that patients with end colostomies had higher rates of laparotomy for reversal and larger blood loss during reversal. The multi-institutional study did have a major limitation in the fact that only 43% of the study population had destructive colon injuries as an indication for diversion. Another 50% of the patients were diverted secondary to rectal injuries, and 7% were because of perineal/gluteal wounds following trauma. Rectal injuries are not the same as colon injuries. It is well accepted in the literature that most extraperitoneal rectal injuries that cannot be repaired primarily are safely managed with loop ostomy as opposed to end colostomy.^{20,21} Nevertheless, the multi-institutional study offers evidence for using a loop ostomy over an end ostomy when managing destructive colon injuries requiring diversion.

The current study demonstrates the largest single institution study of diversion technique for destructive colon injuries in the current literature. Furthermore, it is the only study that evaluates how the presence of a concomitant PVH influences reversal outcomes. Much like the reversal of an end ostomy, repair of a PVH is generally a long procedure that can be associated with longer hospital stays and increased morbidity.^{22–24} It is then not surprising that, for patients with a PVH in the current study, there was no difference in ostomy reversal operative time, reversal length of stay, or reversal complications between those with a loop ostomy and those with an end ostomy. However, for patients without a concomitant PVH, management of the patient with an anastomosis with proximal loop ostomy reduced reversal-related complications, reversal operative time, reversal length of stay, and hospital charges without compromising initial morbidity.

The first major limitation of the study is the retrospective design. This precludes the exclusion of selection bias and unevaluated differences as potential confounding variables. In addition, this allows only for associations to be made and cannot account for all potential confounding differences. For example, we do not know the exact reason why a surgeon chose to perform diversion with an end ostomy instead of performing an anastomosis with a proximal diverting loop ostomy. Although our algorithm gives us clear indications for diversion, it does not elucidate which method of diversion is superior. Diversion with end ostomy was more commonly performed earlier in the study period. Diversion with a proximal loop ostomy was commonly performed later in the study. This suggests an overall paradigm shift in technique but the exact reasons for this change cannot be gleaned from a

retrospective review. Furthermore, a vast number of colostomies are performed at our institution for rectal injuries, and these were not evaluated. Because of the fact that these are almost exclusively managed with loop colostomies, we did not feel it appropriate to include these injuries in a study evaluating diversion of destructive colon wounds. Also, by performing a subset analysis in patients with and without a PVH, we have subjected the data to a potential type 2 error because of the overall small sample of patients. We acknowledge this and suggest readers interpret this subgroup analysis with caution. Finally, this study was limited to the medical records available at our institution. We were not able to record if patients underwent reversal procedures at another institution or if they were readmitted to another institution for a postoperative complication.

CONCLUSION

For patients with PVH, anastomosis with proximal loop ostomy provided no benefit over end colostomy. However, for patients without PVH, an anastomosis with proximal loop ostomy reduced reversal-related complications, operative time, length of stay, and hospital charges without compromising initial morbidity. Thus, for all patients, anastomosis with proximal loop ostomy should be the preferred method of diversion, if required, following destructive colon injury.

AUTHORSHIP

L.J.M. and J.P.S. conceived the study. N.R.M., R.H.L., M.S.I., R.C., and J.P.S. performed the retrospective chart review and created the database. N.R.M. and J.P.S. performed the literature search. L.J.M. and J.P.S. performed the data analysis, and N.R.M. drafted the initial article. All authors performed the critical revision of the article and participated in the data interpretation and writing.

DISCLOSURE

The authors declare no conflicts of interest.

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