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ORIGINAL SCIENTIFIC REPORT

Penetrating Colon Trauma—the Effect of Injury Location on Outcomes

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Abstract

Background There is limited evidence to suggest that the more distal a penetrating colonic injury, the poorer its expected outcome, prompting consideration of diversion rather than anastomosis when faced with left colonic injury. The clinical outcomes of penetrating colonic trauma in relation to their anatomical location within the colon were reviewed.

Methods A review was performed over eight years (2012—2020) of all patients over 18 years who had sustained penetrating colon injury and presented to our trauma centre in South Africa. Direct comparison was made between right colon vs left colon injuries.

Results A total of 450 patients were included; right colon: 260, left colon: 190. Gunshots predominated in the right colon, and the PATI was higher in this group. There were minimal differences in admission physiology and blood gas parameters between groups, but higher damage control surgery and ICU admission rates for the right colon group. There were similar rates of primary repair, anastomosis, and stoma between groups. Leak rates were no different between the two groups, and although overall complication rates were higher for the right colon, there was no difference with regard to gastro-intestinal and other complications, nor for mortality. While regression analysis did identify PATI to be a risk factor for overall complications and mortality, it failed to do so for anastomotic leak.

Conclusion Our study did not demonstrate any difference in anastomotic leak rates or mortality between right vs left colonic injury. We recommend that all colonic injuries should be treated on their own merit, balanced against the patient's condition, regardless of anatomical location within the colon.

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Introduction

As the management of colonic trauma has evolved over the last sixty years, there has been a move away from diversion towards repair of the colonic injury [1]. Despite this, there remain concerns regarding the potential for anastomotic failure, as this complication is associated with significant morbidity and mortality. A number of clinical risk factors for anastomotic failure have been proposed [2]. Among these risk factors is left-sided colon injury, which has been shown by a number of studies to carry a higher risk of anastomotic breakdown than right-sided colonic injury. Cullinane et al. [3] performed a meta-analysis in 2019 with the intention of updating the Eastern Association for the Surgery of Trauma (EAST) guideline for the management of these injuries. The authors found the data to be significantly heterogenous and variable, and as such firm recommendations could not be made. A conditional recommendation was made, however, that resection and anastomosis can be considered for most patients with a destructive colonic injury. They went on to caution against this in patients with a delay to definitive surgery of more than 12 h, in the presence of shock, red cell transfusion of more than six units, severe contamination, and left colon injury. In light of these recommendations, we have been reviewing our large cohort of patients with colonic trauma and interrogating the relationship between these identified risk factors and the outcome of penetrating colonic injuries. The objective of this study was specifically focussed on reviewing the relationship between site of the colonic injury and clinical outcome, with the aim of optimizing the management algorithm for patients with penetrating colonic injury.

Materials and methods

Clinical setting

The Pietermaritzburg Metropolitan Trauma Service (PMTS) has maintained a hybrid electronic registry (HEMR) of all trauma patients since 2012. We have institutional review board approval to keep and use this data, namely the Biomedical Research Ethics Committee (BREC) of the University of KwaZulu Natal. The ethics numbers are BE 207/09 and BE215/17. For the purpose of this study, we reviewed the eight-year period from January 2012 to April 2020.

The study

All patients older than 18 years who had a colonic injury recognized during celiotomy for penetrating abdominal trauma were identified. All patients who did not survive longer than 72 h, or who were transferred to another institution, were excluded from the cohort. The following data were extracted for each patient: basic demographics, mechanism of trauma, physiology on presentation. The Penetrating Abdominal Trauma Index (PATI) and Injury Severity Score (ISS) were worked out for each individual patient. The site of the injury and the operative approach to each injury was recorded. For the purposes of this study, a single injury was defined as all patients with either a single injury or a through-and-through injury to a single part of the colon. Patients with wounds affecting more than one part of the colon were regarded as having "multiple injuries". The "right colon" was regarded as the part of the colon extending from the caecum up to the middle colic artery, and the "left colon" was regarded as the remainder of the colon. Injuries to the intraperitoneal rectum were not included in this study. Where resections of destructive injuries of the right colon were necessitated, right hemicolectomy was performed with ileocolic anastomosis or diversion, while in the left colon, segmental resection was performed with colo-colic anastomosis or diversion. Length of ICU stay, length of hospital stays, in-hospital morbidities, and mortality were reviewed. Complications were classified as per Clavien–Dindo classification [4].

Management protocol for colonic injury

All non-destructive perforations are debrided and repaired with a single layer absorbable suture. Destructive wounds are those where more than half of the bowel wall is involved and in which the mesenteric vascular supply is interrupted. [5] In these cases, the damaged section is resected, and an end-to-end anastomosis is fashioned. If one or more of the following factors are present: hypothermia <34 °C, acidosis as defined by a pH <7.2, serum lactate >5 mmol/L, and multiple extensive intra-abdominal injuries, then a damage control strategy is embarked upon. All non-destructive colonic wounds are repaired, whilst destructive injuries are ligated and placed back in the abdomen. On completion of the index damage control laparotomy, the patient is transferred to ICU where aggressive attempts are made to restore the patient's physiology. Once the patient's physiology has been reconstituted, a repeat laparotomy is undertaken. This usually takes 24–48 h to achieve. At the repeat laparotomy, there are two options to manage the ligated ends of large bowel, depending on the patient's physiology and the

judgement of the operating team. Patients who are still dependent on inotropic support and with a persistently elevated lactate >2 mmol/L, as well as those with marked disseminated contamination at initial laparotomy, undergo a diversion. Delayed anastomosis is eschewed in this group.

Statistical analysis

We performed statistical analysis with GraphPad Prism 7.01 for Windows (GraphPad Software, San Diego, the USA). We investigated normality of data with the Shapiro–Wilk test and by graphical inspection. All variables are given as median unless stated otherwise. Normally distributed continuous variables were compared using students independent, two-tailed t-test. All categorical data sets were compared using Chi-squared or Fishers exact test. The Mann–Whitney U was used to compare non-normally distributed continuous variables. Multiple linear regression for variables of interest was calculated using Excel for Windows. A p value of < 0.05 was regarded as representing statistical significance.

Results

Over the eight years between January 2012 and April 2020, a total of 584 patients had a penetrating colonic injury diagnosed at laparotomy. Of these, 29 died within 72 h and 13 were transferred to an intensive care unit (ICU) at another centre, which were excluded from the analysis. One patient was excluded because of incomplete records and insufficient data for this analysis. Of the remaining 541 patients, 91 had multiple colonic injuries and were excluded from this review. A total of 450 patients with a single colonic injury were included in the final review, and comparison was made between 260 right and 190 left colonic injuries. Inclusions and exclusions for this study are presented in Fig. 1.

Patient demographics and mechanism of injury are presented in Table 1, where direct comparison was made between patients with right versus those with left colonic injuries. There was a higher proportion of GSW in the right colon compared to the left, while for SW, there was a higher proportion in the left colon.

The admission physiology and injury severity scores are listed in Table 2. Tachycardia was more pronounced for patients with right colon injury, but there was no difference in other physiological parameters. Although pH, base excess, and lactate were worse in the right colon group, only pH reached statistical significance. PATI was higher

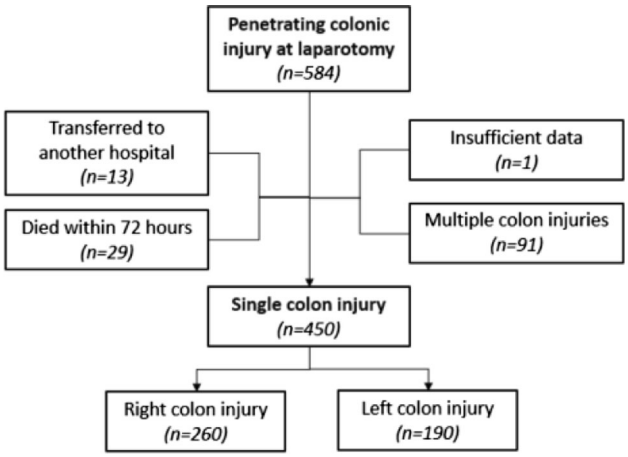


Fig. 1 Patient flow

for those with right-sided injuries (21 vs. 18; $p = 0.028$), while there was no difference in ISS between groups.

Management of patient and bowel is outlined in Table 3, together with related outcomes. Right colon injuries were associated with a higher rate of damage control surgery ($p = 0.001$) and ICU admission ($p = 0.02$). We could not demonstrate any differences between the two cohorts in terms of the rates of primary repair, anastomosis, or diversion. There was no difference in ICU or hospital length of stay between groups.

As outlined in Table 4, the leak rates for primary repairs (4% vs. 1%; $p = 0.095$) and for anastomoses (1% vs. 0.5%; $p = 0.882$) were no different between the right and left colon injury groups. The overall complication rate was higher for right colon injuries (45% vs. 30%, $p = 0.001$); however, the difference was not significant for any of the individual categories of GI, wound, respiratory, or renal complications. The mortality rates in both groups were similar (6% vs. 3%; $p = 0.195$).

Regression analysis was performed for three main outcomes. For a dependent outcome of "any complication", both left and right colon injuries, admission pH, and PATI were identified as independent risk factors (Table 5). For anastomotic leak, admission pH was found to be an independent risk factor, while the site of colonic injury, PATI, and ISS was not (Table 6). For mortality, admission pH and PATI were found to be independent risk factors, but not site of injury or ISS (Table 7).

Discussion

There have been concerns around primary repair of left-sided colonic trauma ever since mandatory diversion began to be challenged in the nineteen-seventies. The objections

Table 1 Demographics and mechanism of injury

	Right colon injury (n = 260)	Left colon injury (n = 190)	p value
Demographics			
Male	250	169	0.003
Female	10	21	
Age (y)	27	29	0.189
Mechanism			
Gunshot wound (%)	132 (51)	68 (36)	0.002
Stab wound (%)	129 (49)	121 (64)	

Table 2 Admission physiology and injury severity score

	Right colon injury	Left colon injury	p value
Pulse	98	94	0.018
MAP	89	88.8	0.559
RR	20	18	0.224
pH	7.37	7.4	0.014
Base Excess	− 2.0	− 0.7	0.186
Bicarbonate	22.7	23.5	0.148
Lactate	2.2	1.8	0.378
Injury severity score	16	16	0.811
PATI score	21	18	0.028

Table 3 Management and length of stay outcomes

	Right colon injury (n = 260)	Left colon injury (n = 190)	p value
Damage control (%)	51 (20)	16 (8)	0.001
ICU admission (%)	97 (37)	51 (27)	0.02
Primary repair (%)	187 (72)	139 (73)	0.772
Anastomosis (%)	23 (9)	9 (5)	0.093
Stoma (%)	50 (19)	42 (22)	0.455
Length of stay			
ICU length of stay (days; median)	6.5	6	0.35
Hospital length of stay (days; median)	8	8	0.09

were based on an anatomical understanding of the colonic blood supply and on clinical experience in elective colorectal surgery. It is difficult to extrapolate findings from elective surgery to emergency surgery, as there are major differences between the two disciplines. Trauma patients tend to be younger than elective patients and do not have the same spectrum of pre-existing co-morbidities. The concerns about repairing injuries to the left-sided colon exemplify the problems associated with extrapolating clinical experience from elective surgery to trauma surgery.

This analysis showed no differences between patients with left- and right-sided colonic injuries in terms of admission physiology, injury severity score, or blood gas parameters, aside from more marked tachycardia and worse pH in the right colon group. We could not demonstrate any difference in terms of the rates of primary repair, anastomosis, or stoma, between the two groups. The right colon

Table 4 Leak rates, complication rates, mortality

	Right colon injury (n = 260)	Left colon injury (n = 190)	p value
Leak rate			
Primary repair leak (%)	9 (4)	2 (1)	0.095
Anastomotic leak (%)	3 (1)	1 (0.5)	0.882
Complications and mortality			
Any complication (%)	116 (45)	56 (30)	0.001
GI complication (%)	55 (21)	27 (14)	0.056
Wound complication (%)	45 (17)	33 (17)	0.987
Respiratory complication (%)	40 (15)	23 (12)	0.322
Renal complications (%)	18 (7)	11 (6)	0.594
Mortality (%)	15 (6)	6 (3)	0.195

Table 5 Regression analysis using any complication as the dependent outcome

	Coefficient	p value
Left colon injuries	0.5351	0.011
Right colon injuries	0.5467	0.001
pH	− 0.7073	0.013
PATI	0.7509	0.002
ISS	0.0002	0.999

Table 6 Regression analysis: Anastomotic leak

	Coefficient	p value
Left colon injuries	− 0.953	0.116
Right colon injuries	− 0.402	0.110
pH	0.659	0.019
PATI	0.001	0.726
ISS	0.005	0.274

Table 7 Regression analysis: Mortality

	Coefficient	p value
Left colon injuries	0.046	0.085
Right colon injuries	0.047	0.137
pH	− 0.608	< 0.00001
PATI	0.515	0.001
ISS	0.037	0.469

group had higher rates of damage control and ICU admissions, and a higher rate of overall complications but otherwise there were no differences between groups in terms of leak rates or GI complication rates, and no difference in mortality.

Several authors have published findings regarding outcomes of right versus left colon injuries. A study by Thompson et al. [6] found that after comparable treatment methods had been used for right and left colon injuries, the mortality and morbidity rates were very similar in both groups. The authors concluded that penetrating trauma to the right and left colon should be managed in the same manner, regardless of anatomical or physiological differences between the two parts of the colon. Murray and coworkers [7] examined 140 patients of whom 85 had undergone colonic resection and colo-colonic anastomosis for trauma. These authors could not show any difference in anastomotic leak rate between the right and left colon. In another study by Sharpe et al. [8] involving 469 patients with penetrating colon injury, multivariable logistic regression could not identify location of the colonic wound as an independent predictor of morbidity or mortality. This after adjusting for injury mechanism, shock index, base excess, operative management, and 24 h transfusion requirement. Similarly, Fouda et al. [9] in a retrospective study of 110 patients with colon injury did not find left colon injury to be a risk factor for a higher complication rate.

Conversely, however, a Western Trauma Association multi-institutional study by Burlew et al. [10] which examined 204 patients with enteric injuries found that leak rates increased as injury location progressed towards the left colon. However, the patients in that study were all managed with an open abdomen, and it is not clear what effect of the open abdomen had on this particular finding. In our study, we did not make a distinction between patients with open abdomens and those without.

A retrospective study by Mansor et al. [11] on 63 cases with gunshot injury to the colon during the Libyan revolution conflict found that postoperative complications were most frequent in patients with injuries to the transverse colon (87.5%), followed by right colon (27.7%) and sigmoid colon (18.1%). In the same vein, and also from a

conflict situation, Steele et al. [12] studied 175 patients with colorectal injuries (96% penetrating) and found at multivariate regression analysis that injuries to the transverse colon were independently associated with higher rate of mortality. In our study, although not displayed in our results above, we did see a higher overall complication rates for transverse colon injuries compared to any other part of the colon ($p = 0.011$); however, mortality was not higher.

A study by Saar and coworkers from Cape Town [13] showed that higher ISS, PATI, and shock on admission were risk factors for mortality. In our study, admission pH and PATI were shown to be independent risk factors. The main potential confounder in our study was that the right colonic group had a higher incidence of gunshot wounds. It was shown in a previous study from our unit that colonic gunshots tend to fare worse than colonic stab wounds [14]. The right-sided group in the current study had a higher mean PATI, reflecting higher abdominal injury severity. However, while regression analysis did identify PATI to be a risk factor for overall complications and mortality, it failed to do so for anastomotic leak.

The results of both this study and the pre-existing literature suggest that the concerns about repairing left-sided colonic injuries are over-stated. There is no overwhelming body of evidence to suggest that injury to any particular part of the colon should be treated differently from any other. Notably, a left colon injury in itself should not be regarded as an indication to divert rather than repair.

Conclusion

The current literature suggests that colostomy should be selectively considered for patients with high risk factors, including a delay more than 12 h, shock, red cell transfusion of more than six units, severe contamination, and left colon injury. Our study has failed to demonstrate increased risk of suture line breakdown, gastro-intestinal complications, or mortality for patients with left-sided colonic injury. Considering this and other currently available data, colonic injury should be treated in the overall context of the patient's condition, regardless of anatomical location of colonic injury.

Author contributions Oosthuizen GV is the Principal investigator. Buitendag J, Variawa S, and Čačala SR contributed to preparation and analysis of data, preparation of manuscript. Kong VY was involved in data analysis and manuscript preparation. Couch D contributed to data analysis, statistical analysis, manuscript preparation. Clarke DL is the Supervising author and was involved in data analysis, manuscript preparation.

Declaration

Conflict of interest There are no conflicts of interest and no external funding was used for this study.

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