Diseases of the Colon & Rectum

Management of Penetrating Colon and Rectal Injuries in the Pediatric Patient

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PURPOSE: Management of civilian penetrating colon injuries in the adult has evolved from the universal use of fecal diversion to the highly selective use of colostomy. We hypothesized that a similar management approach was appropriate for the pediatric population. METHODS: A retrospective review of pediatric patients (age <17 years) with a penetrating colorectal injury was performed at six Level I trauma centers for the period January 1990 through June 2001. RESULTS: For the period of review, 53 children with a penetrating colorectal injury were identified. Firearms caused 89 percent of the injuries. The colon was injured in 83 percent (n = 44) of patients and the rectum in 17 percent (n = 9) of patients. The colorectal injury was managed without colostomy in 62 percent (n = 33) and with colostomy in 38 percent (colon = 11, rectum = 9). All rectal injuries were treated with colostomy. The hospital length of stay was longer in the colostomy group (17.6 days *vs*. 11.4 days). The complication rate was higher in the colostomy group (55 percent *vs*. 27 percent), which included two patients with stoma-related complications. There was no mortality in this series. CONCLUSIONS: Primary repair was used safely in most cases of civilian penetrating colon injuries in the pediatric population. All rectal injuries were treated with colostomy in this series. Fecal diversion was used selectively. Colostomy was performed for selected cases of colon wounds associated with shock, multiple blood transfusions, multiple other injuries, extensive contamination, and high-velocity weapons. In the absence of these associated factors, primary repair appears justified. [Key words: Colon trauma; Penetrating trauma; Colostomy; Pediatric trauma; Primary repair; Colon injury; Rectal injury; Gunshot wound; Penetrating wounds]

INTRODUCTION

Management of penetrating colon injuries has evolved from the universal use of fecal diversion to the highly selective use of colostomy.[1,2] The avoidance of routine use of a colostomy has been demonstrated to be safe and cost-effective and to improve quality of life in the adult population.[3–6] As firearm violence increasingly becomes a problem in the pediatric population, clinicians are faced with similar management decisions in the injured child. Little has been reported on the optimal management of nonwartime penetrating colon injuries in the child.[7,8] This study was undertaken to review the current practices

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Table 1.
Patient Demographics

Factor	Any Colorectal Injury	Primary Repair (Colon Injury)	Colostomy (Rectal or Colon Injury)	Colostomy (Colon Injury)
Patients	53	33	20	11
Age (years, mean)	12.2	12.5	11.7	9.3[a]
Male (%)	39 (74%)	24 (73%)	15 (75%)	8 (73%)
Systolic blood pressure (mmHg, mean)	123	126	116	105[a]
Heart rate (bpm, mean)	102	97	111[a]	117[a]
Blood transfused (ml/kg, mean)	7.0	3.0	14.8	24.7[a]
Time to operation (min, mean)	80.0	69.7	97.1	55.3
Patients with any other injury	40 (76%)	22 (67%)	18 (90%)	10 (91%)
Patients with other abdominal injury	35 (66%)	19 (57.6%)	17 (85%)[a]	10 (91%)[a]
Number of associated injuries (mean)	1.98	1.58	2.65	3.73[a]
Hospital length of stay (days, mean)	13.8	11.4	17.6	24.1
Colostomy reversal length of stay (days, mean)		N/A	7.8	9.1
Antibiotic duration (days, mean)	6.8	5.3	9.1[a]	11.7[a]

[a] $P < 0.05$ compared to primary repair group.

and outcome in the management of civilian pediatric patients with a penetrating colon or rectal injury.

METHODS

A retrospective review was performed of children (age <17 years) who sustained a penetrating injury to the colon or rectum. Data were collected for the period January 1990 through July 2001 from six trauma centers (Children's Hospital of Philadelphia, Philadelphia, Pennsylvania; Hospital of the University of Pennsylvania, Philadelphia, Pennsylvania; Cardinal Glennon Children's Hospital, St. Louis, Missouri; Children's Hospital Medical Center, Cincinnati, Ohio; Columbus Children's Hospital, Columbus, Ohio; and Children's Hospital of Pittsburgh, Pittsburgh, Pennsylvania). Patients were identified through local trauma registries and reviewed by a surgeon at the treating institution. Penetrating injuries included gunshot wounds (GSW), shotgun wounds (SGW), stab/piercing wounds (SW), and impalements. Injuries were identified and described from review of the operative note. The degree of soilage was estimated as none, minimal, moderate, or extensive. Details of surgical management were obtained from the operative note. Additional information obtained from the medical record included demographic information, additional injury details, physiologic parameters, management information, complications, and outcome.

Each individual institution received Institutional Review Board approval or waiver as guided by local requirements.

Statistics were performed using standard methods. Chi-squared or Fisher's exact test was used for comparison of frequencies between groups. The Student's *t*-test was used for comparison of means between groups. Differences were considered significant at $P < 0.05$.

RESULTS

For the period of review, 53 children sustained a penetrating injury to the colon or rectum. The injury population had a mean age of 12.2 (±4.2; range, 1-16) years and was predominantly male (73.6 percent). Firearms caused most of the injuries (n = 47, 88.7 percent). These were mostly low-velocity or medium-velocity wounds (including 7 BB guns), with only two shotgun wounds and two rifle wounds. The non-firearm injuries (N = 6, 12.3 percent) included two knife stab wounds, two arrow wounds, one impalement on a stake, and one Rottweiler dog bite (Table 1).

Estimation of the degree of intra-abdominal contamination was made by review of the operative note. In most cases (79 percent) it was noted to be none or minimal (Table 2). Contamination was noted to be none or minimal in 97 percent of patients treated without colostomy and in 50 percent of patients who were managed with a colostomy.

The injury to the colon was most commonly located in the transverse colon (36 percent). Eight patients (15 percent) had injuries in more than one segment of colon (Table 3). The majority of colon injuries were described as full-thickness (86.7 percent). Only three (5.7 percent) were described as devitalizing and four (7.6 percent) as partial thickness or contusion.

Table 2.
Estimated Intra-Abdominal Contamination at Time of Laparotomy

Soilage	Any Colorectal Injury No. (%)	Primary Repair (Colon Injury) No. (%)	Colostomy (Rectal or Colon Injury) No. (%)	Colostomy (Colon Injury) No. (%)
None	19 (36)	16 (48.5)	3 (15)[a]	0[a]
Minimal	23 (43)	16 (48.5)	7 (35)	3 (27)
Moderate	7 (13)	0	7 (35)[a]	5 (46)[a]
Extensive	3 (6)	1 (3)	2 (10)	2 (18)
Unknown	1 (2)	0	1 (5)	1 (9)
Total	53	33	20	11

[a] $P < 0.05$ compared to primary repair group.

Table 3.
Location of Colorectal Injury

	Any Colorectal Injury No. (%)	Primary Repair (Colon Injury) No. (%)	Colostomy (Rectal or Colon Injury) No. (%)	Colostomy (Colon Injury) No. (%)
Patients	53	33	20	11
Total Colorectal Injuries	69	45	24	15
Right	11 (21)	9 (27)	2 (10)	2 (18)
Transverse	19 (36)	17 (52)	2 (10)[a]	2 (18)
Left	11 (21)	7 (21)	4 (20)	4 (36)
Sigmoid	11 (21)	6 (18)	5 (25)	5 (46)
Rectum	9 (17)	0	9 (45)[a]	0
Multiple	8 (15)	6 (18)	2 (10)	2 (18)

[a] $P < 0.05$ compared to primary repair group.

Associated injuries were common in this population; 76 percent of patients had at least one other injury, with a mean of 2.1 total other injuries per patient. Overall, 66 percent of patients were noted to have at least one other intra-abdominal injury at the time of laparotomy. The average number of associated abdominal injuries was 1.7. Associated abdominal injuries were more common in the colostomy group than in the primary repair group (85 percent *vs.* 57.6 percent, $P = 0.038$). The most common associated injury was to the small bowel (45 percent). A major vascular injury was noted in five patients (9 percent) (Table 4). All three patients who had hypotension (systolic blood pressure <90) had wounds to the colon and were treated with colostomy.

Rectal injuries were seen in 9 of 53 (17 percent) patients. Mechanisms of injury varied (7 gunshot wounds and 2 impalements), but most involved direct trauma to the buttock or rectum. Associated bladder injury was common, found in four patients. All injuries were full thickness. All patients were treated with colostomy and drain placement.

The study group was subdivided into younger preteen children (age <13 years) and adolescents (ages 13-16 years). There were 21 children in the younger group and 32 in the older group (Table 5). The age, weight, and baseline physiologic parameters (heart rate and blood pressure) differed significantly between the two groups (Table 5). The male:female ratio, injury mechanism, area of colon injured, and amount of soilage were the same. The rates of multiple colon injuries, other intra-abdominal injuries, small bowel injury, and major vascular injuries were also the same (Table 5). There were more rectal injuries in the older group (n = 8, 25 percent) than in the younger group (n = 1, 4.8 percent); however, this did not reach statistical significance ($P = 0.071$). On subgroup analysis of only colon injuries (rectal injuries excluded) the data were similar. When the older and younger groups were compared, the results were the same (with the exception of systolic blood pressure, which was no longer significantly different).

Management

All patients were managed with exploratory laparotomy and treated with intravenous antibiotics (mean length of antibiotic therapy, 6.8 days). The average time to operation was 80 (±121; range, 10-640)

Table 4.
Associated Abdominal Injuries Noted at Time of Laparotomy

Injury	Any Colorectal Injury No. (%)	Primary Repair (Colon Injury) No. (%)	Colostomy (Rectal or Colon Injury) No. (%)	Colostomy (Colon Injury) No. (%)
Patients	53	33	20	11
At least one	35 (66)	19 (57.6)	17 (85)[a]	10 (91)
Small bowel	24 (45)	12 (36)	12 (60)	9 (82)[a]
Duodenum	4 (8)	2 (6)	2 (10)	2 (18)
Stomach	11 (21)	5 (15)	6 (30)	5 (46)
Kidney	4 (8)	1 (3)	3 (15)	3 (27)[a]
Liver	11 (21)	7 (21)	4 (20)	4 (36)
Spleen	7 (13)	5 (15)	2 (10)	2 (18)
Bladder	4 (8)	0	4 (20)[a]	0
Major vascular	5 (9)	3 (9)	2 (10)	2 (18)
Diaphragm	3 (6)	3 (9)	0	0
Pancreas	3 (6)	1 (3)	2 (10)	2 (18)

[a] $P < 0.05$ compared to primary repair group.

Table 5.
Older *vs.* Younger Patients

Factor	Younger (Ages 1-12)	Older (Ages 13-16)
Patients	21	32
Age (years, mean)	7.9	15.1[a]
Systolic blood pressure (mmHg, mean)	114	128[a]
Heart rate (bpm, mean)	114	95[a]
Weight (kg, mean)	27.6	65.0[a]
Gunshot wound	18 (86%)	29 (91%)
Male	15 (71%)	24 (75%)
Patients with associated injuries	14 (67%)	26 (81%)
Number of associated injuries (mean)	2.00	1.97
Small-bowel injury	9 (43%)	15 (47%)
Time to operation (min, mean)	117	56
Blood transfused (ml/kg, mean)	10.5	4.3
Hospital length of stay (days, mean)	15.7	12.6
Patients with any complication	6 (28.6%)	14 (43.8%)
Patients with infectious complication	3 (14.3%)	3 (9.4%)
Time to takedown (days, mean)	79	131

[a] $P < 0.05$.

minutes. The younger children had a longer time to surgery (117 minutes *vs.* 56 minutes, $P = 0.07$), but this did not reach statistical significance. There were no deaths in the series.

The colon injury was managed without colostomy in 33 patients. Primary repair (repair or resection with anastomosis) was performed in 32 (62.3 percent) patients. One patient had a colon contusion that did not require repair. The remaining 20 (37.3 percent) patients had a fecal diversion procedure (Table 6). All nine patients with a rectal injury were managed with colostomy.

All patients with shotgun or rifle wounds (n = 4) were treated with colostomy. The six non-firearm wounds were evenly divided between colostomy (2 arrow wounds and 1 impalement) and no colostomy (2 knife stab wounds and 1 dog bite).

When an injury was repaired primarily, a double-layer closure was preferred in 81.8 percent of cases. When a resection with primary anastomosis was performed, a stapling device was used in 55 percent of patients. When the anastomosis was handsewn, it was a two-layer closure in 75 percent and a single layer in 25 percent. The abdominal wound was closed in 86.8 percent of cases, including 80 percent of patients with moderate or extensive soilage.

The overall average hospital length of stay (LOS) was 13.8 (±17.4; range, 3-104) days. The colostomy group had a longer LOS (17.6 days *vs.* 11.4 days, $P = 0.22$). When only patients with colon wounds were compared, the difference was more pronounced (24.1 days for colostomy *vs.* 11.4 days for primary repair, $P = 0.055$).

When the subgroup of patients with colon wounds was examined, the patients treated with colostomy seemed to be more seriously injured, both physiologically and anatomically. When the colostomy group was compared with the no-colostomy group, there were significant differences (Table 1). The colostomy group had a higher heart rate, lower systolic blood pressure, a higher rate of associated intra-abdominal

Table 6.
Management of Penetrating Colorectal Injuries in Children

Operative Technique	Colorectal No. (%)	Colon No. (%)	Rectum No. (%)
Patients	53	44	9
No Colostomy	33 (62.3%)	33 (75.0%)	0
Primary Repair	32 (60.4%)	32 (72.7%)	0
Simple Oversew	23 (43.4)	23 (52.3)	0
Resection with anastomosis	9 (17.0)	9 (20.5)	0
No treatment (colon) contusion	1 (1.9)	1 (2.3)	0
Colostomy	20 (37.7)	11 (25.0)	9 (100)
Resection with colostomy (Hartman's)	16 (30.2)	9 (20.5)	7 (77.8)
Protective proximal colostomy with distal repair or anastamosis	4 (7.5)	2 (4.5)	2 (22.2)

injuries, more associated injuries, and more blood transfused (Table 1).

Three patients were initially managed with the technique of damage control.[9] These patients had more associated injuries (5.3 *vs.* 1.8, $P = 0.002$), longer LOS (45.7 days *vs.* 11.8 days, $P = 0.0006$), and more blood transfused (1711 ml *vs.* 123 ml, $P = 0.0001$).

Complications

There were a total of 30 complications noted in 20 patients (Table 7). The most common complication was a partial or complete bowel obstruction in seven patients (13 percent). Three patients had atelectasis and two had sepsis. There was one case each of pancreatic fistula, rectal stricture, urine leak, hemorrhage, seizure, urinoma, fungemia, dehydration, pelvic abscess, urinary tract infection, pancreatitis, extremity compartment syndrome, deep vein thrombosis, wound infection, psoas abscess, foot drop, coagulopathy, and duodenal fistula. The number of patients with any complication was higher in the colostomy group than in the primary repair group (55 percent *vs.* 27 percent, $P < 0.05$.). Stoma-related complications were noted in two patients (10 percent of patients treated with colostomy). Infectious complications were noted in six patients (4 with colostomy and 2 without colostomy). One infection in the primary repair group was a wound infection and psoas abscess in a patient with an isolated stab to the right colon. Another primary-repair patient developed abdominal sepsis from a duodenal fistula. There was no difference in the rates of any complication, any infectious complication, or sepsis between the younger and older groups.

An infectious complication developed in 20 percent of patients with moderate or extensive soilage but in only 7.1 percent of patients with no soilage or minimal soilage.

DISCUSSION

Woodhall and Oschner were the first to truly challenge the routine use of fecal diversion in all patients with penetrating colon injuries.[10] Stone and Fabian published the first prospective randomized study showing that primary repair can be safe in a selected group of patients.[11] Since the publication of these landmark studies, the safety, efficacy, and possible improved outcomes without the use of fecal diversion for all penetrating colon injuries have been demonstrated. The Eastern Association for the Surgery of Trauma has recommended that the data support a "standard for primary repair of non-destructive penetrating colon wounds" and "resection and anastomosis for stable patients without significant associated injuries."[12]

There is a paucity of published data to support similar management algorithms in the civilian pediatric population. The few reports regarding penetrating colon injury in children have focused on wartime injuries.[7,8] Slim *et al.* conducted a retrospective survey of 44 children from Beirut, Lebanon in 1975-1976. Most of these penetrating colon injuries were from shrapnel and high-velocity bullets. They performed primary repair in 24 patients and colostomy in 20 patients. The mortality rates (16.6 percent *vs.* 10 percent) and outcomes were similar in their patient population.[7] Dokucu *et al.* reported a series of colon injures in children in Turkey. The mechanism of injury in these children was significantly different, with the majority being explosive injuries (land mines and grenades) or shotgun wounds. However, their conclusions about the safe use of selective primary repair children are the same as those for adults.[8] In Chatter-

Table 7.
Complications

	Any Colorectal Injury No. (%)	Primary Repair (Colon Injury) No. (%)	Colostomy (Rectal or Colon Injury) No. (%)	Colostomy (Colon Injury) No. (%)
Patients (total in group)	53	33	20	11
Patients with any complication	20 (38)	9 (27)	11 (55)[a]	7 (64)
Patients with infectious complication	6 (11)	2 (6)	4 (20)	4 (36)[a]
Sepsis	2 (4)	1 (3)	1 (5)	1 (9)
Stoma related	2 (4)	0	2 (10)	0
Bowel obstruction	7 (13)	4 (12)	3 (15)	0

[a] $P < 0.05$ compared to primary repair group.

jee and Jagdish's series[13] of 32 children in India with intestinal injuries, there were only seven injuries to the colon or rectum, all treated with colostomy. The penetrating injuries described in this small series (4 sharp objects, 3 bull gores, 2 rectal thermometers, 1 shotgun, and 1 monkey bite) are very different from those encountered in our multi-institutional series of pediatric patients with penetrating colorectal injuries. These injuries were the result of mechanisms more commonly encountered in civilian practice (i.e., low-energy firearm wounds).

The frequency of these injuries in adults has enabled researchers to conduct large prospective, randomized studies evaluating management strategies for penetrating colonic injuries.[5,11,14] The adult studies have shown lower mortality,[4] shorter LOS,[4] and lower complication rates[4,11,15,16] with primary repair. Although firearm violence is on the rise in children and adolescents,[17] the number of these cases in the pediatric population does not allow a similar undertaking. We used multicenter retrospective data to try and gain insight into current management practices for pediatric penetrating colonic trauma.

Our pediatric data on the selective use of fecal diversion for these colon wounds have many similarities to those of large adult studies. Most of the patients in our series of children were treated safely without the routine use of colostomy. Patients with a colon injury treated with primary repair had a shorter LOS (11.4 days *vs.* 24.1 days, $P = 0.055$), as in a large prospective series of adults.[5] When all patients are examined, our series had a higher rate of total complications in patients treated with fecal diversion (55 percent *vs.* 27 percent, $P < 0.05$). If only colon wounds are examined, the rate of infectious complications is also significantly higher (36 percent *vs.* 6 percent, $P < 0.05$), which corresponds to data from a recent meta-analysis.[15]

To avoid the possibility of skewing the data with the older adolescent children, we broke down the data into the younger and older age groups. As expected, the weight and vital signs differed significantly (Table 5). However, the remaining demographic, management, and outcome data were similar. The older children did have more rectal injuries, but this difference was not significant. The younger children spent more time in the operating room, however, this did not reach statistical significance (Table 5). This additional one-hour delay may reflect the transfer of these younger patients from referring hospitals to a pediatric trauma center.

Overall, 20 patients were treated with a colostomy. Of these, 19 patients had an elective operation to take down their colostomy. The average delay between the first operation and readmission for elective takedown was 111.9 (±68.6; range, 40-290) days. The average additional LOS was 7.8 (±2.6; range, 4-15) days. Other authors have documented the cost savings and improved quality of life that can be realized by avoiding routine colostomy use in adults.[6,18]

In addition to the added cost and decreased quality of life, four colostomy-specific complications were noted. Two patients required additional surgery for small-bowel obstructions due to internal hernia at the colostomy site. One patient had an iatrogenic small-bowel injury (enterotomy) at the time of the colostomy takedown. One patient had a rectal stricture after being treated with a Hartman's procedure. These four complications may have been unavoidable. However, if fewer colostomies are performed, then there should be fewer colostomy-related complications.

Many other studies have emphasized that primary repair is not appropriate for all patients with a penetrating colonic wound. Controversy exists about relative contraindications such as shock, multiple blood transfusions, gross contamination, long delay to operation, and multiple other abdominal injuries.[4,5,11,14] The patients in our series of penetrating colon wounds

who were treated with primary repair were highly selected by the individual surgeon at the time of exploration. The patients treated with colostomy had higher heart rates, lower systolic blood pressure, more blood transfused, more associated injuries, and a longer duration of antibiotic treatment (Table 1). No colostomy-specific complications occurred in this group.

In our retrospective multi-institutional series, it is difficult to determine the exact rationale and reasoning for the use of colostomy at the time of an individual's surgery. However, we tried to determine (from the data available) the reasons for fecal diversion. All nine rectal injuries were treated with colostomy. Of the 11 colostomies performed for colon wounds, 9 had at least one easily identifiable "definite" or "relative" contraindication (based on prior adult data) to primary repair. There were two patients with extensive contamination and other major injuries from shotgun wounds, three patients with severe hemorrhage, two patients with large devitalized areas of colon, and two patients with multiple abdominal injuries. There were two patients who had moderate spillage alone as the only identifiable risk factor.

All nine patients with rectal injuries were treated with colostomy and drain placement. All bladder injuries (n = 4) were found in association with a rectal injury. The close anatomic relationship of the bladder to the rectum dictates that if one is injured, we must search diligently for associated injury to the other.

This current study certainly does have some limitations, including its retrospective nature and small number. Because of its multicenter data accrual, we were unable to obtain an objective measure of injury, such as an Injury Severity Score (ISS) or Penetrating Abdominal Trauma Index (PATI). If this had been available, it might have shown that the more injured patients were the ones treated with colostomy. Had we been able to grade the colon injury on a standard scale, such as the Acute Injury Score (AIS) for the colon, we might have gained more insight into ways of determining if primary repair is safe in a specific patient.

CONCLUSIONS

Primary repair can be used safely in most cases of civilian penetrating colon injuries in the pediatric population. Fecal diversion was used selectively. All rectal injuries were treated with colostomy in this series. Colostomy was performed for cases of colon wounds associated with shock, multiple blood transfusions, multiple other injuries, extensive contamination, and high-velocity weapons.

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