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Safety of Primary Repair in Penetrating Colorectal Injuries during Current Yemeni War

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Aims: This study aimed to evaluate the septic colon related-complications and death after primary repair (PR) of penetrating colon injuries (PCIs).
Study Design: Retrospective observational study.
Place and Duration of Study: This study was conducted at the Department of Surgery, of the field hospital in the Yemeni city; Taiz. Patients' files were reviewed from April 2015 to January 2020 during the current Yemeni Civilian war.
Methodology: We included 56 consecutive PCI patients exclusively managed with PR (55 men, 1 woman; age range 14-60 years). All cases were secondary to ballistic mechanism of injury (MOI), mostly gunshot wound (GSW), with no one stab wound (SW). Forty-two cases underwent PR solely by enterorrhaphy, and 14 cases required at least one primary anastomosis (PA) for their PR. A total of 64 colon wounds were managed within 24 hours by PR (whether enterorrhaphy for non-destructive PCIs [50 of 64] or PA for destructive injuries [14 of 64]).
Results: Nineteen patients (33.9%) developed 30 colon-related infectious complications. No one died as a result of colon injury. Incisional surgical site infection (SSI) was the most common complication, occurring in 17.9% of cases, followed by missile-tract wound infection in 16.1%. Relatively less common complications were enterocutaneous fistula with a rate of 10.7%, in addition

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to a rate of 5.4% for intra-abdominal abscess and 3.6% for fascial dehiscence. Remarkably, no one patient suffered from major suture-line failure with peritonitis. Only seven patients required re-operation for these complications: three enterocutaneous fistula cases required diversion stoma, two cases required debridement for wound infection, and two cases required closure of abdominal wall after fascial dehiscence.

Conclusion: Apart from wound infections, the one-stage PR procedure can be an acceptable option for PCIs in the resource-limited settings of battlefields. Further research is needed to determine absolute contraindications to PR to avoid stoma complications.

Keywords: Colorectal injury; penetrating trauma; complications; primary repair; war.

1. INTRODUCTION

Penetrating colorectal injuries (PCIs), are more commonly observed in military trauma (5-10%) than in civilian trauma practice (1-3%) [1,2]. Over the last two centuries, the death rate from colonic injuries has dropped dramatically, from the high 60% in World War I and 40% in World War II to just 3% in the last two decades [3–7]. Coincidently, a little change in morbidity occurred. Studies show septic complications ranging from 16% to 33% [3–6]. These changes are thought to go along with the advancements in the field of trauma surgery, colon injury operative techniques, perioperative care, and antibiotic prescription [8–10].

Management of traumatic colorectal injuries has undergone a dramatic change over time [11]. This has evolved from conservative management during the Civil War to selective primary repair (PR) amidst the World War I era [12]. At the outbreak of World War II, the management of colorectal trauma remained debated and inconsistent. In 1943, Sir W.H. Ogilvie, a British surgeon who served in both World Wars, famously concluded in his book “Forward Surgery in Modern War” that mandate proximal diversion to treat all war-related colorectal injuries [13]. That same year, the Surgeon General of the USA Thomas Parran, Jr. mandated proximal diversion for all PCIs sustained in combat [14].

As the war ended, trauma-trained surgeons enrolled in civilian surgery practice. Nevertheless, mandatory colostomy became the unchallenged gold standard of care for PCIs until the late 1970s [11]. With the concomitant advancement of perioperative care and early definitive management; civilian surgeons started to advocate PR in selected cases of PCI.[15,16] This was supported by Woodhall and Ochsner's study [15] that enrolled 50 patients with civilian PCIs. They found two fatalities among 24 patients treated by PR, compared to nine among 26 patients treated with diversion stoma. Concluding that, fecal diversion for PCIs is not essential for a good outcome in civilian trauma practice. The PR approach for civilian-related PCIs was subsequently validated by more evidence; including five multiple randomized controlled trials [17–21] and two meta-analyses [22,23].

Nowadays, the trend of PR for PCIs has gained widespread acceptance among both military and civilian surgeons, with a limited role for diversion stoma. Nevertheless, there is still some skepticism by many surgeons, especially in the presence of certain risk factors such as destructive colon injuries, severe contamination, multiple injuries and delay in treatment. [2,7,8,24–27]

Given the ongoing debate on PCIs management and the paucity of studies addressing the safety of one-stage PR during wartime, particularly for patients managed in the austere environment of low-to-middle-income countries (LMICs) setting such as Yemen. It was the primary aim of this study to explore the surgical outcomes of our local experience in PR for PCI, performed in the urgent/emergent setting (within 24 hours of sustaining injury). Focusing on cases managed at the Field Hospital of Al Rawdha, Taiz city during the current Yemeni Civilian War from April 2015 to January 2020.

2. METHODOLOGY

This was a retrospective, observational study, conducted at the Field Hospital of Al Rawdha in Taiz City during the period from April 2015 to January 2020, of the current Yemeni Civilian War. We included all patients older than 14 years old who were admitted and underwent laparotomy for penetrating abdominal trauma that proved the intra-operative finding of devascularization or full-thickness colorectal

injury, and in whom primary operative repair was performed in the urgent/emergent setting (less than 24 hours from the time of injury to operation). On the other hand, we excluded patients younger than 14 years old, PCI secondary to blunt mechanism of injury (MOI), patients who underwent laparotomy and PR after a delay of 24 hours or more since the injury's onset, or patients whose management included any form of diversion stoma proximal to the PR.

Information was retrospectively obtained from patients' files, discharge notes, and electronic hospital databases. The recorded data included age, gender, MOI, comorbid conditions, shock at initial operation, number of blood bags transfused on the day of admission, colon segment injured, severity of colon injury (destructive or non-destructive), type of PR performed (enterorrhaphy, or primary resection and anastomosis [PA]), associated intra-abdominal injuries and use of antibiotics. Postoperative course was analyzed for in-hospital colon-related infectious complications, need for reoperation, or death secondary to these complications. *Colon-related infectious complications* were defined as the in-hospital development of superficial/deep surgical site infection (SSI), missile-tract wound infection, intra-abdominal abscess, fascial dehiscence, enterocutaneous fistula, and/or major suture line leak/peritonitis. *Colon-related mortality* was defined as in-hospital death secondary to colon-related infectious complications.

Non-destructive colon wounds are injuries to the colon that can be repaired with limited debridement and enterorrhaphy [28,29]. *Destructive colon injuries* are those injuries that require segmental colon resection as colonic integrity is lost (indicated by the involvement of more than 50 % of the colon circumference, complete colon transection, or significant tissue loss); or segmental devascularization secondary to mesenteric injury [28,29].

PR was defined as: 1) debridement with primary suturing (enterorrhaphy) for non-destructive PCIs, or 2) PA for destructive PCIs; in the absence of any proximal diverting stoma. At the time of this study, there was no strict protocol in place for the management of PCIs. and the decision to proceed with PR or diversion was left to the discretion of the attending surgeon. As such, all management decisions were made on a case-by-case basis by the attending surgeon. However, a general policy of PR was favored over diversion for PCIs, whenever feasible. After focal debridement or resection of the injured colon. Almost all PRs were performed in one-layer fashion using 3-0 Vicryl® (polyglactin 910) running submucosal sutures. At the end of the operation, the abdomen was irrigated with a copious amount of warmed saline until the effluent turned clear. This frequently required 5**–**10 liters. An abdominal drain was left in the most dependent peritoneal pouch and exteriorized through a separate abdominal wound. Almost all laparotomy wounds were closed using a size 1 Prolene® (polymer of polypropylene) running sutures. In all cases, the skin was closed primarily with an interrupted 2-0 nylon (polyamide) or Prolene®. Perioperative antibiotics were administered for a variable duration of time.

Although there is no distinct definition or classification for *colorectal suture line leak* [30,31] After Bruce et al. [32] and Chambers et al. [33] we classified leaks into major clinical leaks that present as diffuse postoperative peritonitis, and minor clinical leaks that present as postoperative enterocutaneous fistulas or intra-abdominal abscesses. *Major clinical leaks*: These leaks present as diffuse postoperative peritonitis can be defined as *peritonitis* that persists or recurs following the apparently adequate surgical source control by PR during initial exploratory laparotomy, and proper antibiotic therapy. This is determined by the presence of an associated compatible clinical illness, with diffuse intraoperative or radiologically confirmed spillage of luminal contents due to severe disruption of the PR suture line (whether primary suture closure or PA). These leaks are potentially life-threatening and require reintervention (usually reoperation). [30,32–38] *Minor clinical leaks/postoperative enterocutaneous fistulas* were defined as aberrant communications between any portion of the gastrointestinal tract and the skin/wound. Initial diagnosis was made by the clinical observation of local inflammation, e.g., fever (temperature >38Cº), leukocytosis (white cell count >10,000/liter), and enteric or colon contents leakage through the abdominal wall wounds or operatively placed drainage catheters. This leak may appear in imaging studies, and/or intraoperatively [32,33,39]. Minor clinical leaks that cause only intra-abdominal collection was considered separately as intra-abdominal abscess.

Statistical analysis was performed using the 24th version of SPSS (Statistical Package for the

Social Sciences) software. Each enrolled patient's ID number was represented on an SPSS datasheet's rows. Each element in the questionnaire was represented in an SPSS datasheet's column and each categorical variable question's answers were given a code. Coding was saved on an external cross-reference sheet. Descriptive statistics were calculated for categorical and continuous variables. Categorical variables were presented as frequencies and percentages. Continuous variables were presented as mean, median, interquartile range (IQR) or standard deviation. Graphical displays and tables were used to clarify some variables. Statistical analysis was performed by using the unpaired Student t-test or Mann-Whitney rank-sum test for continuous variables, and chi-squared or Fisher's exact for categorical variables where appropriate. Statistical significance was set at a *P*-value < 0.05.

3. RESULTS

3.1 Demographic Data and Patient Characteristics

During this study, we included 56 consecutive patients with PCI who were admitted and managed by PR at Al Rawdha Hospital in Taiz City over the period from April 2015 to January 2020 of the current Yemeni Civilian War. All patients were brought to the operating room within less than 24 hours of the injury.

Most of the patients were young, healthy men having a median age of 25 (range, 14–60) years, with 55 male and 1 female. Only five patients had pre-existing comorbidities. The most common MOI were gunshot wounds (GSWs) that occurred in 35 patients (62.5%), followed by shrapnel penetrating injuries secondary to blast explosion that occurred in 12 patients (21.4%), unspecified projectile-related injuries whether GSW or blast MOI in nine patients (16.1%). Surprisingly, no patient with a stab wound (SW) was observed. As shown in Table 1.

Eight patients have sustained multiple-segment PCIs, making a percentage of 14.3%. All of them get two-segment injuries, giving rise to a total of 64 colorectal wounds in our 56 patients. The 64 wounds were distributed as follows: 15 PCIs in cecum involved 26.8% of the patients, five PCIs in ascending colon involved 8.9% of the patients, 22 PCIs in transverse involved 39.3% of the patients, nine PCIs in descending involved 16.1% of the patients, nine PCIs in sigmoid involved 16.1% of the patients, and two PCIs in intra-peritoneal rectum involved 3.6% of the patients. Additionally, two PCIs occurred in unknown colon segments in 3.6% of the patients, as shown in Fig. 1. For purposes of localization, we divided the intra-peritoneal large bowel into right and left colons, based on the embryologic origin, as illustrated in Fig. 1. The right colon includes the cecum, ascending colon, hepatic flexure, and proximal two-thirds of the transverse colon; while the left colon includes the distal third of the transverse colon, descending colon, splenic flexures, sigmoid colon, and intra-peritoneal rectum [40,41]. Overall, 20 patients have at least one left-colon injury, constituting 35.7% of the study population.

Table 1. Demographics, characteristics and outcomes of patients undergoing primary repair for penetrating colorectal injury

Variable	n = 56
Age in years; median (IQR)	**25 (22-34)**
Sex (%)	
Male	98.2% (55)
Female	1.8% (1)
Presence of comorbidity (%)	8.9% (5)
Mechanism of injury (%)	
Gunshot wounds	62.5% (35)
Blast related	21.4% (12)
Unspecified projectile-related	16.1% (9)
Stab wound	0% (0)
Shock at initial operation (%)	**42.9% (42)**
Site of penetrating colon injury (%)	
Right-sided colon injury	28.9% (33)
Left-sided colon injury	32.1% (18)
Both left and right sides colon injuries	5.4% (3)
Unknown site	3.6% (2)

Variable	n = 56
Multiple segment penetrating colon injury (%)	**14.3% (8)**
Severity of penetrating colon injury (%)	
Non-destructive	75% (42)
Destructive	25% (14)
Associated intra-abdominal injuries (%)	**71.4% (40)**
Number of associated intra-abdominal injury (%)	
None	28.6% (16)
Single associated organ injury	35.7% (20)
Two or more organs injury	35.7% (20)
Median 24-hour of transfused blood (IQR)	**3 (1-5) units**
Blood transfusion (%)	
≥ 2 units	66.1% (37)
< 2 units	33.9% (19)
Median of hospital length of stay (IQR)	10 (7–16.5) days
Median for ICU length of stay (IQR)	1 (0–4) days
Required ICU admission	**29 (51.8%)**
Complications (%)	
Colon-related	33.% (19)
Non-colon-related	26.8% (15)
Mortality (%)	0% (0)

ICU; intensive care unit, IQR; interquartile range, n; number

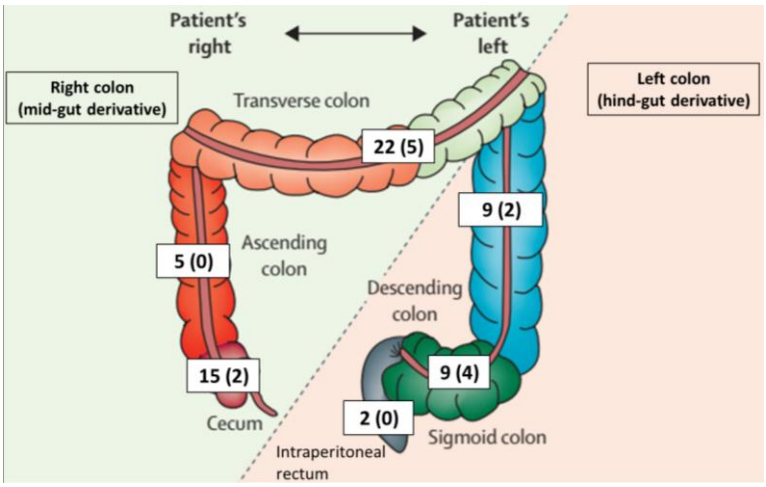

Fig. 1. Frequency distribution of 64 penetrating colorectal injuries by colon segment, destructive injuries are shown in parentheses

NB. Additionally, two injuries occurred in unknown site, of them one was destructive injury

Only 16 patients (28.6%) sustained isolated PCI. While the remaining 40 patients (71.4%) have concomitant injuries to a total of 73 extra-colic intra-abdominal organs. Twenty patients (35.7%) have acquired single associated intra-abdominal injury, 12 patients (21.4%) have two organs' injuries, six patients (10.7%) have three organs injuries, and two patients (3.6%) have five organs injuries.

In Fig. 2, the distribution of intra-abdominal organs that were co-injured with the large bowel in our 56 patients is detailed.

The most associated intra-abdominal injury was to the small bowel, which occurred in about 46.4% of the patients (26 of 56). followed by abdominal vascular injury in 14.3% (8 of 56), pelvic fracture in 10.7% (6 of 56), kidney injury in 10.7% (6 of 56), liver laceration in 8.9% (5 of 56), and retroperitoneal hematoma in 7.1% (4 of 56). Relatively less common associated injuries involved the stomach, duodenum, stomach, and spinal cord, which constituted 5.4%, each (3 of 56). Diaphragm injuries occurred at a rate of 3.6% (2 of 56). While the least concomitant intra-abdominal organs co-injured were the spleen,

ureter and pancreas at a rate of 1.8%, each (1 of 56). Additionally, other organs injuries as gall bladder or adrenal gland injuries occurred in 7.1% (4 of 56).

Systolic blood pressure less than 90 mmHg during the initial operation defining intraoperative shock, occurred in 24 patients (42.9%), while the remaining 32 (57.1%) patients maintained a stable hemodynamic status during the initial operation [42]. As shown in Fig. 3. In our study, patients with shock had a significantly higher rate of associated abdominal vascular injury in comparison to normotensive patients (29.2% vs. 3.1%, *P* = .01). As expected, patients with shock received a median of 5 (IQR, 3-8.5) blood units which is significantly higher than the normotensive patients median of 2 (IQR, 1-3) blood units, (*P* < .05).

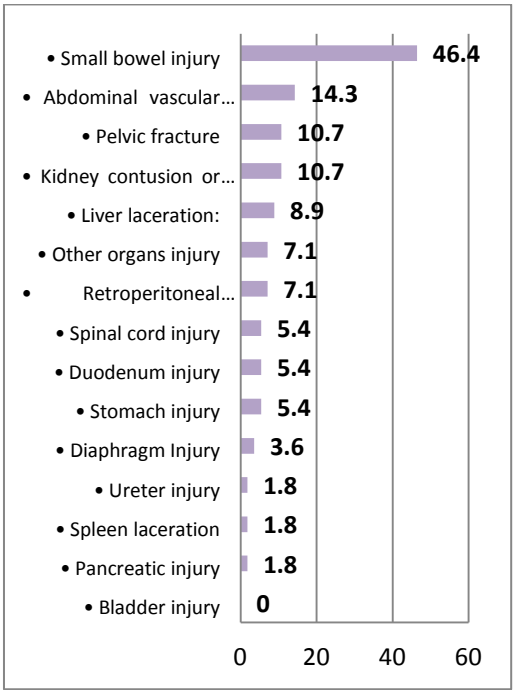

Fig. 2. Percent distribution of associated intra-abdominal organs injuries in the study patients (n=56)

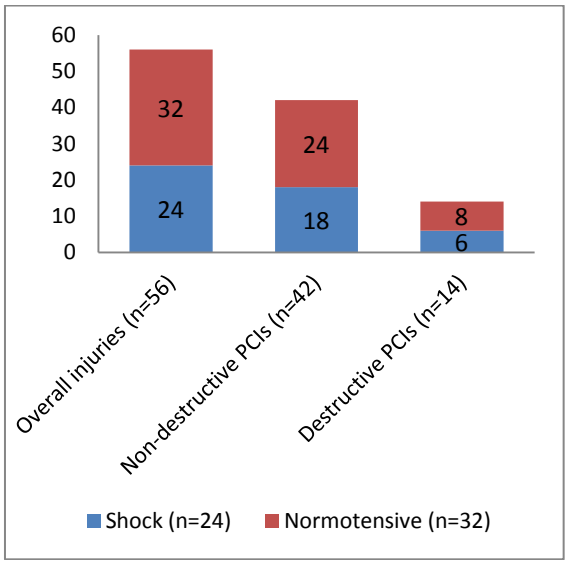

Fig. 3. Frequency distribution of shock among patients with penetrating colorectal injury in general and according to severity of injury (whether non-destructive or destructive)

Of the 56 patients, 47 patients (83.9%) received a total of 195 units of whole blood on the day of admission, making an overall median of 3 (IQR, 1–5) blood units**,** with an insignificantly higher median of 4 (IQR, 1-5) units after destructive PCI in compared to the 2.5 (IQR, 1-4) units after non-destructive PCI; (*P* = .50). While only nine patients (16.1%) didn't receive any blood transfusions (six patients with non-destructive and three with destructive PCIs, [*P* = .68]). Amid the 56 cases in our study, 37 patients (66.1%) received two or more blood units (64.3% of those with non-destructive injuries and 71.4% of those with destructive injuries, [*P* = .75]).

Regarding the management of the total 64 colon wounds that were found in the study, 52 (81.2 %) colorectal wounds were non-destructive that were managed with enterorrhaphy (of them, 15 patients had undergone at least enterorrhaphy for left-sided PCI). And only 14 colorectal injuries (21.1%) were destructive that required PA (with six patients had underwent at least one PA for left-sided PCI). Thus, among the 56 patients in this study, 25% (14 of 56) have sustained at least one destructive PCI that required PA (eight performed for right colon injuries and six performed for left colon injuries). However, on univariate analysis, the relationship between the side and the severity of PCI was insignificant (*P* = .55).

Furthermore, there was no significant relationship between the mechanism and the severity of injury (*P* = .31). Fig.1. above illustrates the distribution of 64 colon wounds by site and severity. Amid the 14 patients with destructive PCIs, the site of the anastomoses was colo-colic in seven patients, colo-rectal in four, and ileo-colic in two patients. In addition to one anastomosis in an unknown site.

Overall, our study group consisted of 56 PCI patients, with 64 intra-operatively confirmed PCIs that was primarily repaired by; simple enterorrhaphy solely in 42 patient (75%), PA solely in 11 patient (19.6%), and by enterorrhaphy in addition to PA in three patients (5.4%).

3.2 Mortality

No one death resulted from colon-related septic complications in this study.

3.3 Morbidity

In this study, 33.9% of the patients had one or more colon-related infectious complications. These 19 patients had acquired a total of 30 complications. The most common complications were superficial/deep surgical-site infection (SSI) that occurred in 17.9% of cases (10 of 56), followed by missile-tract wound infection in 16.1 % (9 of 56). Relatively less common complications were enterocutaneous fistula with a rate of 10.7% (6 of 56). In addition to rates of 5.4% (3 of 56) for intra-abdominal abscess and 3.6% (2 of 56) for burst abdomen (fascial dehiscence), in order from highest to lowest. Remarkably, no one patient suffered from major suture-line failure with peritonitis. On the other hand, non-infectious complications of laparotomy occurred in two patients (3.6%) who suffered from early postoperative intestinal obstruction secondary to intestinal adhesions. The distribution of surgical outcomes recorded for the study population, as a whole, and according to the severity and hence type of PR, is shown in Table 2. These outcome variables did not differ significantly by severity and type of PR performed; or in other word there was no difference in the rate of post-operative complications between patients with non-destructive PCIs who underwent enterorrhaphy and those with destructive injuries managed by PA.

Seven of the 19 patients who acquire colon-related infectious complications were re-operated (12.5% of the study population); three enterocutaneous fistula cases required diversion stoma, two cases required debridement for wound infection, and two cases required the closure of abdominal wall after burst abdomen. Two patients required percutaneous aspiration of intra-abdominal abscess. Antibiotic management was modified in 17 patients due to colon-related septic complications, and four cases for non-colon-related infections. Apart from infectious complication, two cases required adhesiolysis for early postoperative intestinal obstruction.

4. DISCUSSION

PCIs can be managed by either PR or diversion stoma. During World War II, the standard procedure to repair these injuries was diversion: since then, diversion with stoma creation has dominated the treatment of both military and civilian colonic injuries [43]. Over the past three decades, PR has gained popularity and has become more accepted at least for non-destructive PCIs inflicted in the civilian setting [8,22–24,26,44].

Table 2. Miscellaneous complications after primary repair of penetrating colon injury in general, and according to severity and surgical technique (whether non-destructive injuries primarily sutured (enterorrhaphy), or destructive injuries requiring primary anastomoses)

Complications	Overall patients (n=56)		Non-destructive PCI (n=42)		Destructive PCI (n=14)		*P* value*
	n	%	n	%	n	%	
Colon related septic[$]	19	33.9	14	33.3	5	35.7	.87
Superficial/deep surgical-site infection	10	17.9	6	14.3	4	28.6	.25
Missile-tract wound infection	9	16.1	6	14.3	3	21.4	.68
Intra-abdominal abscess	3	5.4	2	4.8	1	7.1	1.00
Fascial dehiscence	2	3.6	1	2.4	1	7.1	.44
Minor suture line leak/ Enterocutaneous fistula	6	10.7	3	7.1	3	21.4	.16
Major suture line leak/peritonitis	0	0.0	0	0.0	0	0.0	-

$ Presence of one complication or more

**The P values were derived from two-tailed Fisher's exact test or x2 test for categorical variables and Mann-Whitney test for continuous variables, n; number*

This was not the case for war injuries, as surgeons began to appreciate the difference between military and civilian injuries and noted that civilian low-velocity gunshot wounds and stabbings were of a different nature than the high velocity devitalizing military wounds.[22–24,45,46] Additionally, war injuries differ from their civilian counterpart at least in three ways: involving a different spectrum of injuries, happening in austere environments, and dealing with mass casualties. Thus, civilian trauma practices may be unsuitable in certain combat settings[11,24,47] Published papers reporting outcomes of war-related colon injuries are inconsistent, but most of them support at least a limited role for the PR of colon injuries.[8,46,48–50] The goal of the present study was not meant to compare the outcomes of PR vs. fecal diversion, as many other studies have shown equivalent or improved outcomes.[8,26,46,48–50] Rather, this study aimed to evaluate the current management and outcome of patients with PCIs on the modern-day battlefield in the context of increasing willingness to perform PR.

4.1 Mortality

If PCIs are not treated appropriately, fatal septic complications may be ensued; nonetheless, debate still exists concerning the standard treatment [11,45,51]. In our study, no one death was related to the PR of PCI. This is similar to Mitchao et al. [26] who found no death related to PCI among 88 patients whose PCIs were repaired primarily. And compare well to other studies that recorded a mortality rate approaching 0% [29,51–53]**.**

4.2 Morbidity

It has been well established that colorectal injuries result in more complications than do injuries to most of the other abdominal organs. This indeed reflects the septic morbidities from fecal spillage and its associated colonization ~~with~~ by many various aerobic and anaerobic microorganisms. As in the absence of bowel injury, the rate of septic complications in patients with penetrating abdominal injuries is basically the same as in elective procedures. [54]

In the present series of 56 cases exclusively managed by PR, we found a 33.9% rate (19 of 56) of colon-related septic morbidity (33.3% [14 of 42] after enterorrhaphy and 35.7% [5 of 14] after PA, *(P* = 1.00). This is relatively higher than those rates reported after the PR of PCIs in civilian settings: 9.1% reported by Mitchao et al. [26], 16.2% reported by Shazi et al. [51], 18% reported by Gonzalez et al. [20], 14.3% reported by Chappuis et al. [18], 2.3% reported by Sasaki et al. [49], 22.5% reported by Kamwendo et al. [55], and 24% of Demetriades et al. [53]. However, it mimics the 29.5% rate after PR reported by George et al. [54] among PCIs in the USA (26% for the enterorrhaphy group and 50%

for the PA group), and lesser than the 42% reported by Bulger et al. [56] from USA. Similar to these two civilian studies we didn't exclud the presence of extensive spillage, shock, or associated injuries. When compared to war-based studies, our septic morbidity rate also mimic the 29% reported by Vertrees et al. [49] who studied patients from Iraqi war, and the 32.5% reported by Mansor et al [57] study that involved Libyan war-injured patients. Other military-based studies had also reported high rates of colon-related complications. For example, Duncan et al. [58] reported a complication rate of 48%, Hudolin et al. [48] reported 27%, Stankovic et al. [59] reported 39.6%, and Strada et al. [60] reported a rate of 15%.

Indeed, comparisons between morbidity and mortality of this study and other series are difficult, first of all, because this study was conducted in a war-setting, while most of the literature included PCIs from civilian-settings. One major distinction of war-setting injuries is the MOI, in comparison to civilian-setting; with a relatively larger proportion of simple PCI resulting from SWs and low-energy penetrating MOI in the latter setting. [10,54,56,58,61–63] Additionally, resource limitations associated with the treatment of war victims could affect their management and outcomes[58,61,62,64]. Thus, the apparently high septic morbidity rate related to PCI in our study can be partly interpreted by the military nature of our PCI-MOI, that our complications rate of 33.9% approaches the those reported in military studies [48,59,60]. Despite the privilege of the younger age of this study population, the warfare-injury mechanisms involve weapons with higher-velocity. In addition to the different tactics of militias' war-style in compared to traditional regular-army war-style, with more use of snipers and landmines by militias, may had played a role in exaggerating morbidities. Not to forget the deterioration of the security situation, that led to weapons spreading including those causing high-velocity injuries among the community. [65,66] Conseq uently, our patients had more destructive patterns of PCI requiring PA (25%). In contrast to our war-based study, in the civilian work of George et al. [54], only 12 (12.6%) PAs were performed from an overall of 95 PRs. Gonzales et al. [20] also performed only 5 PA of the 89 PR in his civilian trauma patients [20]. Indeed our PR success rate of 66.1% is more comparable with recent military series that quote leaks rate of 13 to 30 percent [11,24], and success rate from PR as 11 to 72 [1,48,57].

A second distinction between the studies that address the management of PCIs, is that the exclusion and inclusion criteria are different and not always clearly defined. For instance, when patients who sustained a seromuscular injury with no full-thickness PCI are included, the morbidity and mortality rates will apparently be lower. Similarly, many authors either perform diversion or exclude patients with comorbid conditions [23,29,67,68], multiple concomitant intra-abdominal injuries [23,68] or destructive PCIs [25,67–69], as well as those with higher amount of blood transfusion [29,67,68] or in the presence of significant peritoneal soiling by feces [68–70]; resulting in an artificially low morbidity and mortality rates. In the contrary, this study included all patients having the so-called "high-risk criteria" for PR in PCI.

The third possible explanation for our apparently higher rate of colon septic complications; is that incisional SSI and missile-tract wound infection have significantly contributed to our colon septic complications rate. In another word, these two infectious outcomes formed 19 of the overall 30 colon-related complications found in our 19 complicated cases. As incisional SSI was present in 50.6% (10 of 19) of patients with complications ($P < .05$), and missile-tract wound infections were found in 47.4% (9 of 19) of patients with complications ($P < .05$). The most likely exposition for the high rates of incisional SSI (17.9%), is that all our cases underwent primary closure of skin laparotomy wounds during the initial surgery even in the presence of gross fecal peritoneal contamination. Although we have found relatively high rate of missile-tract wound infection (16.1%), we lacked substantial data regarding the severity and exact management of missile-tract wounds, which limited our proper assessment of these infections. Unlike our study findings, there were no superficial wound infections of the operative wound sites in the study of Neill et al. [71]. The author ascribed it to the fact that all skin laparotomy wounds were left open to heal by secondary intention. Velmahos et al. [72] also observed that primary skin laparotomy wound closure acts only to double the risk of wound infection. Interestingly, if we excluded the ten patients whose PRs were complicated only by wound infection; whether it was only incisional SSI (4 of 10), only missile-tract wound infection (4 of 9), or both types of wound infection (2 of

10); our colon related septic complication would be almost halved from the 33.9% (19 of 56) to 16.1% (9 of 56).

There are several limitations in this study. Besides the low number of patients included, this study was limited by its inherent retrospective design. To be exact, because of the limited or incomplete documentation and the lack of a preoperative management algorithm, it is difficult to discern specific patients' and surgeons' variables that might influence the decision to perform a colostomy as opposed to PR; hence evaluating their impacts on outcomes is impossible. Another limitation of this database includes the absence of important data regarding important confounders such as the exact time delay from injury onset to PR, duration of operation, Penetrating Abdominal Trauma Index (PATI), severity of contamination, and the details of GSW characteristics as well as surgeons' variables include specialty, certificate, training, and experience. Perhaps the most considerable limitation is the lack of outcomes data related to a comparative group of patients managed by stoma creation followed by its takedown, or damage control surgery followed by definitive management; hence judging the best strategy to manage PCIs is difficult. Furthermore, this study was performed using data collected during a specified period, from a single field hospital in a territory under the control of legitimate government backed by Saudi-Led Coalition, in LMIC with a weak health system(Moyer et al. 2019). Hence, all our injured cases had been inflicted by interpersonal violence or Houthi-militia fighters which depend on characteristic weaponry including rifles, land mines, tanks, artillery, and anti-aircraft weapons.[65] If this study expanded to include further hospitals or trauma centers and extended to enroll patients managed by surgeons who gain more experience with cases load after 7-years of war, the study results may have differed. Finally, outcomes are limited to morbidity and mortality encountered from the time of admission till discharge and readmission at the same hospital. Subsequent hospitalizations, procedures and outcomes outside of the initial hospital could not be captured within this database. Nevertheless, this article represents the contemporary update on outcomes of PR in war-related PCI in the austere environment of battle-field hospital at a LMIC like Yemen.

5. CONCLUSION

War-related PCIs endure a challenging clinical entity associated with significant morbidity. However, civilian studies showed that this was not related to management techniques whether fecal diversion or PR. Given the limitation of this study and the current paucity of evidence from military trauma [11,24,73]; we cannot draw any definitive conclusions. Nevertheless, our high complications rate (particularly SSIs and missile-tract infections) contrasts sharply with the low leak rate, and lack of peritonitis or mortality arising from PR of PCIs in otherwise young, fit patients; has been provocative to employ a definitive one-stage procedure for war-related PCIs as an acceptable option; avoiding the routine fecal diversion and all of its disadvantages including the need for multiple procedures. However, more rigorous scientific research will be needed to affirm the safety of this approach. These studies should address the factors that make the patient at risk to develop devastating complications or mortality, in comparison with different options; whether PR, fecal diversion or damage control surgery. After this, a safe algorithm for PCIs can be developed. Thus, ongoing efforts should be paid for better documentation and data capturing using data collection proforma may help elucidate the patient- and surgeon-specific factors that affect outcomes of PCIs management. Finally, in the light of our high wounds infection rate; future studies should better address the different variables and managements strategies of laparotomy skin and missile-tract wound to gain the best outcomes.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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