Original Research Article

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

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). As eight patients had multiple PCIs, the whole 56 patients inflicted a total of 64 colon injures. All of them were managed within 24 hours by PR (whether primary suture for non-destructive PCIs [50 of 64] or primary anastomosis [PA] for destructive injuries [14 of 64]). Forty-two cases underwent PR by primary suture/s and 14 cases required at least PA for their PR. All cases were secondary to ballistic mechanism of injury (MOI), mostly gunshot wound (GSW), with no one stab wound (SW).
Results: Nineteen patients (33.9%) developed 30 colon-related infectious complications. No one death was related to colon injury occured. The most common complications were incisional surgical site infection (SSI) which occurred in 17.9% of cases, followed by missile-track wound infection in 16.1 %. Relatively less common complications were enterocutaneous fistula in 10.7%, in addition 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 and peritonitis. Only seven patients were re-operated 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 is safe and effective management for PCIs in the resource-limited settings of battlefields.

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 civilian trauma practice (1-3%) [1,2]. Mortality of colorectal injuries has changed dramatically over the last two centuries; from the high rates of 60% in World War I and 40% in World War II to a lower rate of 3% in the last two decades [3–6]. Coincidently, a little change in morbidity occurred, studies show septic complications in the range from 16% to 33% [3–6]. These changes are thought to go along with the advancement in the field of

trauma surgery, colon injury operative techniques, perioperative care, and antibiotic prescription [7,8].

Management of traumatic colorectal injuries has undergone a dramatic change over time. This has evolved from conservative management during the Civil War to selective primary repair (PR) amidst the World War I era [9]. At the outbreak of World War II, the management of colorectal trauma remain 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 for all war colorectal injuries mandate proximal diversion to treat [10]. That same year, the Surgeon General of USA Thomas Parran, Jr. mandated proximal diversion for all PCIs sustained in combats [11].

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. With the concomitant advancement of perioperative care and early definitive management; civilian surgeons started to advocate PR in selected cases of PCI. [12,13] This was supported by Woodhall and Ochsner's study [12] that enrolled 50 patients with civilian PCIs, they found that 2 of the 24 patients treated by PR died, compared to 9 of the 26 patients treated with diversion stoma. Concluding that diversion stoma creation is not essential for a good outcome in many civilian encountered PCIs. The practice of PR in civilian-related PCIs was subsequently validated by more evidence; including five multiple randomized controlled trials [14–18] and two meta-analyses [19,20].

Nowadays, the trend of PR for PCIs has gained widespread acceptance among both military and civilian surgeons, with a limited role for diversion stoma. Although 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. [21–23]

Given the ongoing debate of PCIs management and paucity in studies addressing the safety of one-stage PR during wars, 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 what are 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 intra-operatively to have devascularization or full-thickness colorectal injury, 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 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 at the day of admission, colon

segment injured, severity of colon injury (destructive or non-destructive), type of PR performed (primary suturing 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 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.

A *non-destructive colon wounds* are injuries to the colon that can be repaired with limited debridement and primary suture repair [24,25]. *Destructive colon injuries* are those injuries that need segmental colon resection as colonic integrity is lost (indicated by the involvement of more than 50 % of colon circumference, complete colon transection, or significant tissue loss); or segmental devascularization secondary to mesenteric injury [24,25].

PR was defined as: 1) debridement with primary suturing 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. Virtually all PR were performed in one-layer running submucosal sutures, using 3-0 Vicryl® (polyglactin 910). At the end of the operation, the abdomen was irrigated with a copious amount of warmed saline until the effluent turns 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 running size 1 polypropylene suture. The skin was closed primarily with an interrupted 2-0 nylon (polyamide) or Prolene® (polymer of polypropylene) sutures, in all cases. Perioperative antibiotics were administered for a variable duration of time.

Although there is no distinct definition or classification for *colorectal suture line leak* [26]. After Bruce et al. [27] and Chambers et al. [28] we classified leaks into major clinical leak that present as diffuse postoperative peritonitis, and minor clinical leaks that present as postoperative enterocutaneous fistulas or intra-abdominal abscess. *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 defined by the presence of associated compatible clinical illness with diffuse intraoperative or radiologically confirmed spillage of luminal contents due severe disruption of the PR suture line (whether primary suture closure or PA). These leaks are potentially life threatening and require reintervention (usually reoperation). [26–33] *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 on imaging studies, and/or intraoperatively [27,28,34]. 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 patients' 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 in 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 Students 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 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 comorbidity. The most common MOI were gunshot wounds (GSWs) that occurred in 35 patients (62.5%), followed by shrapnel penetrating injury secondary to blast explosion that occurred in 12 patients (21.4%), unspecified projectile-related injury whether GSW or blast MOI in nine patients (16.1%). Surprisingly, no one patient with a stab wound (SW) was observed. As shown in Table 1.

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 Female	 98.2% (55) 1.8% (1)
Presence of comorbidity (%)	8.9% (5)
Mechanism of injury (%) Gunshot wounds Blast related Unspecified projectile-related Stab wound	 62.5% (35) 21.4% (12) 16.1% (9) 0% (0)
Shock at initial operation (%)	42.9% (42)
Site of penetrating colon injury (%) Right-sided colon injury Left-sided colon injury Both left and right sides colon injuries Unknown site	 28.9% (33) 32.1% (18) 5.4% (3) 3.6% (2)
Multiple segment penetrating colon injury (%)	14.3% (8)
Severity of penetrating colon injury (%) Non-destructive Destructive	 75% (42) 25% (14)

Associated intra-abdominal injuries (%)	71.4% (40)
Number of associated intra-abdominal injury (%) None Single associated organ injury Two or more organs injury	 28.6% (16) 35.7% (20) 35.7% (20)
Median 24-hour of transfused blood (IQR)	3 (1-5) units
Blood transfusion (%) ≥ 2 units < 2 units	 66.1% (37) 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 Non-colon-related	 33.% (19) 26.8% (15)
Mortality (%)	0% (0)

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

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 follow: 15 PCIs in cecum involving 26.8% of the patients, five PCIs in ascending colon involving 8.9% of the patients, 22 PCIs in transverse involving 39.3% of the patients, nine PCIs in descending involving 16.1% of the patients, nine PCIs in sigmoid involving 16.1% of the patients, and two PCIs in intra-peritoneal rectum involving 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 colon, 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 [35]. Overall, 20 patients have at least one left-colon injury constituting 35.7% of the study population.

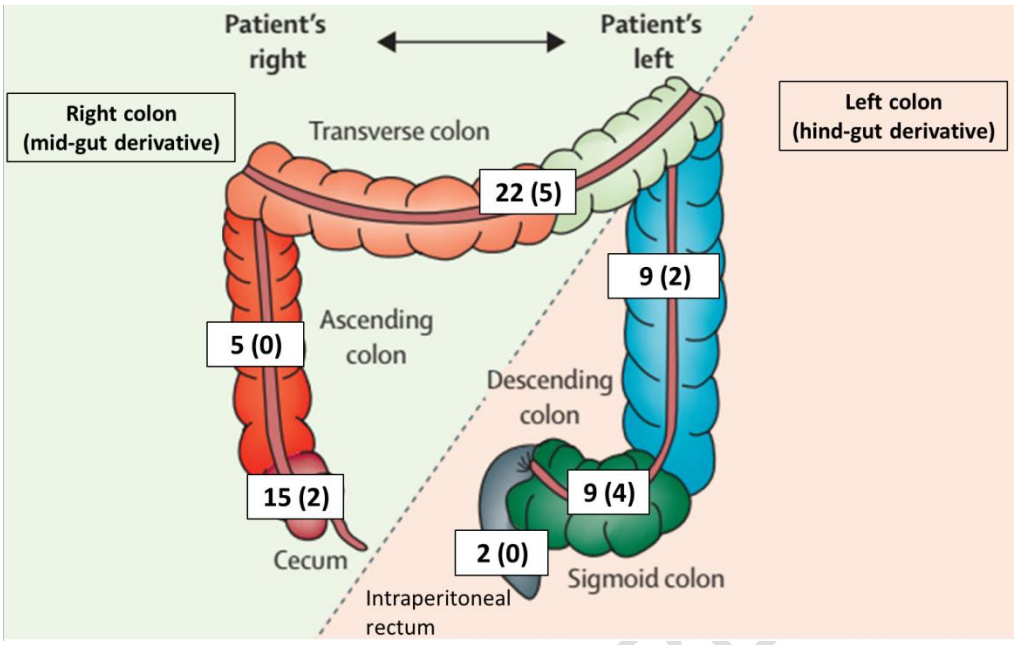

Fig. 1. Frequency distribution of 64 penetrating colorectal injuries by colon segment, destructive injuries are shown in parentheses

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.

The distribution of intra-abdominal organs that were co-injured with the large bowel in our 56 patients is detailed in
Fig. **2**. The most commonly associated intra-abdominal injury was to the small bowel that 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), retroperitoneal hematoma in 7.1% (4 of 56). Relatively less common associated injuries involved the stomach, duodenum, stomach, and spinal cord that 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).

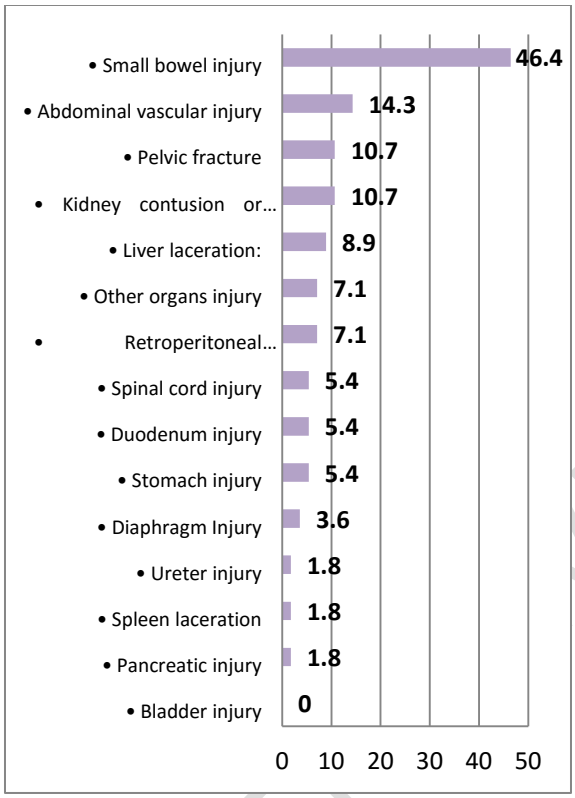

Fig. 2. Percent distribution of associated intra-abdominal organs injuries in the study patients (n=56)

Systolic blood pressure less than 90 mmHg during initial operation defining intraoperative shock, occurred in 24 patients (42.9%), while the remaining 32 (57.1%) patients maintained a stable hemodynamic status during initial operation [36]. 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 median of 2 (IQR, 1-3) blood units among normotensive patients, (P < .05).

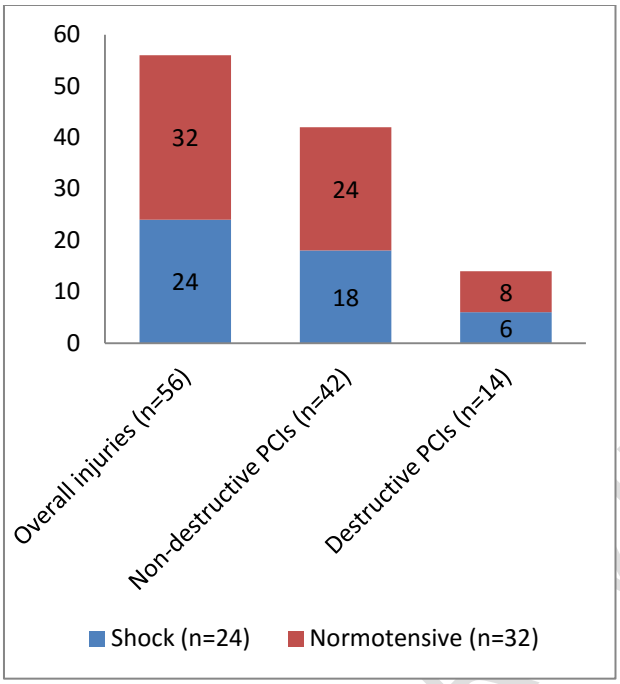

Fig. 3. Frequency distribution of shock among patients with penetrating colorectal injury in general and according to severity of injury (whether non-destructive or destructive)

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 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 and; (*P* = .50). While only nine patients (16.1%) didn't receive any blood transfusion (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 %) colon wounds were non-destructive that were managed with primary suturing (of them, 15 patients had underwent at least primary suturing for left-sided PCI). And only 14 (21.1%) colorectal injuries were destructive that required PA (with six patients had underwent at least 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, the association between the side and severity of PCI was insignificant on univariate analysis (*P* = .55).

Additionally, we found no significant association between the mechanism and severity of injury (*P* = .31). Fig. 1. above illustrated 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 unknown site.

Overall, our study group consisted of 56 PCI patients, with 64 intra-operatively confirmed PCIs that was primarily repaired by; simple suturing solely in 42 patient (75%), PA solely in 11 patient (19.6%), and by primary suturing 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-track 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 primary suturing and those with destructive injuries managed by PA.

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, 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-track 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*

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 dominated the treatment of both military and civilian colonic injuries [37]. Over the past three decades, PR gained popularity and has become more accepted at least for non-destructive PCIs inflicted in the civilian setting [19,20]. This was not the case for war injuries, as surgeons began to appreciate the difference between the 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 [19,20]. Additionally, war injuries differ from their civilian counterpart by 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.[38] Published papers reporting outcomes in war-related colon injuries are inconsistent, but most of them support at least a limited role for PR of colon injuries [39–41]. 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 [39–41]. 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 [42]. In our study, no one death was related to the PR of PCI. This is similar to George et al. [43] who found no death related to PCI among 95 patients whose PCIs were repaired primarily. And compare well to other studies that recorded a mortality rate approaching 0% [44,45].

4.2 Morbidity

It has been well established that colon 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 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. [43]

In the present series of 56 cases exclusively managed by PR, we found a 33.9% rate (19 of 56) colon-related septic morbidity (33.3% [14 of 42] after primary suture and 35.7% [5 of 14] after PA, *(P* = 1.00). This is relatively higher than those rates reported after PR of PCIs in civilian settings: 18% reported by Gonzalez et al. [17], 14.3% reported by Chappuis et al. [15], 2.3% reported by Sasaki et al. [40], 22.5% reported by Kamwendo et al. [46], and 24% of Demetriades et al. [45]. However, it mimic the 29.5% rate after PR reported by George et al. [43] among civilian PCIs in the USA (26% for the primary suture group and 50% for the PA group), as similar to they didn't excluded the presence of extensive spillage, shock, or associated injuries. Our septic morbidity rate also mimic the 29% reported by Vertrees et al. [40] that studied patients from the Iraqi war. Other military-based studies had also reported high rates of colon-related complications, for example, Duncan et al. [47] reported a complication rate of 48%, Hudolin et al. [39] reported 27%, Stankovic et al. [48] reported 39.6%, and Strada et al. [49] 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-setting. One major distinction of war-setting injuries is the MOI, in comparison to civilian-setting; with relatively larger proportion of simple PCI resulting from SWs and low-energy penetrating MOI in the latter setting [43,50]. Additionally, resource limitations associated with the treatment of war victims could affect their management and outcomes. 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 [39,48,49]. Despite the privilege of younger age of this study population, the warfare-injuries 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 security situation, that lead to weapons spread including those causing high-velocity injuries among the community. Consequently, 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. [43], only 12 (12.6%) PAs were performed from an overall of 95 PRs. Also, Gonzales et al. [17] performed only 5 PA of the 89 PR in his civilian trauma patients [17]. Indeed our PR success rate of 66.1% is more comparable with recent military series that quote success rate from PR as 11 to 72 percent [1,39].

A second distinction between the studies that address the management of PCIs, is the difference in 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 be apparently lower. Similarly, many authors either perform diversion or exclude patients with comorbid condition [25], shock [51], multiple concomitant intra-abdominal injuries [51], or destructive PCIs [51,52]; those with higher amount of blood transfusion [25,51]; or in the presence of significant peritoneal soiling by feces [51,52]; hence producing 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-track wound infection had significantly contributed to our colon septic complications rate. In another wards, 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-track 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 wound infection (16.1%), we lacked substantial data regarding the severity and exact management of missile-track wounds, which limited our proper assessment of their infection. Unlike our study findings, there were no superficial wound infections of the operative wound sites in the study of Neill et al. [53], the author ascribed that because all skin laparotomy wounds were left open to heal by secondary intention. Velmahos et al. [54] also observed that primary skin laparotomy wound closure act only to double the risk of wound infection. Interestingly, if we excluded the ten patients whom PRs were complicated only by wounds infection; whether only incisional SSI (4 of 10), only missile-related wound infection (4 of 9), or both types of wounds infection alone (2 of 10); our colon related septic complication will be almost halved from the 33.9% (19 of 56) to 16.1% (9 of 56).

Although, this study is inherently limited by its retrospective observational study design. As the record was insufficiently documented. For example, the database captured neither the exact injury to repair delay time in minutes or hours, duration of operation, Penetrating Abdominal Trauma Index (PATI), severity of contamination, and the details of GSW characteristics. All these variables should be better characterized and addressed in future studies, to allow the extraction of stronger recommendation and better evidence to obtain the best outcomes, after PR of PCIs. And in the light of our high wounds infection rates further study should better address the management and impact of simply leaving laparotomy-skin or GSWs open or closed on the rate of wound infections. Finally, instead of the traditional comparison between PR and diversion stoma after PCI; future studies are also required to find the optimal management techniques including damage control surgery for war-related PCIs in the presence of high-risk factors.

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 stoma diversion or PR. In conclusion, apart from wound infections, whether incisional SSIs and missile-track wound infections, that may have been better managed by leaving open for secondary intention. Our war surgery experience suggests that even in a field hospital with an austere environment and limited resources; a definitive one-stage PR for PCI can be performed safely and satisfactorily. Thus, avoiding all the disadvantages of diversion stoma with the need for multi-staged procedures. In our opinion, the routine use of diversion stoma in war-related PCIs seems no longer to be justified.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

REFERENCES

[1] S.R. Steele, K.E. Wolcott, P.S. Mullenix, M.J. Martin, J.A. Sebesta, K.S. Azarow, A.C. Beekley, Colon and Rectal Injuries During Operation Iraqi Freedom: Are There Any Changing Trends in Management or Outcome?, Dis. Colon Rectum. 50 (2007) 870–877. https://doi.org/10.1007/s10350-007-0235-4.

[2] E.K. Johnson, S.R. Steele, Evidence-Based Management of Colorectal Trauma, J. Gastrointest. Surg. 17 (2013) 1712–1719. https://doi.org/10.1007/s11605-013-2271-9.

[3] D. Demetriades, G. Velmahos, E. Cornwell, T. V. Berne, S. Cober, P.S. Bhasin, H. Belzberg, J. Asensio, Selective Nonoperative Management of Gunshot Wounds of the Anterior Abdomen, Arch. Surg. 132 (1997) 178. https://doi.org/10.1001/archsurg.1997.01430260076017.

[4] G.C. Velmahos, D. Demetriades, E. Foianini, R. Tatevossian, E.E. Cornwell, J. Asensio, H. Belzberg, T. V Berne, A selective approach to the management of gunshot wounds to the back., Am. J. Surg. 174 (1997) 342–6. https://doi.org/10.1016/s0002-9610(97)00098-6.

[5] M. Bala, A.I. Rivkind, G. Zamir, T. Hadar, I. Gertsenshtein, Y. Mintz, A.J. Pikarsky, D. Amar, N. Shussman, M. Abu Gazala, G. Almogy, Abdominal Trauma After Terrorist Bombing Attacks Exhibits a Unique Pattern of Injury, Ann. Surg. 248 (2008) 303–309. https://doi.org/10.1097/SLA.0b013e318180a3f7.

[6] D. Demetriades, B. Rabinowitz, C. Sofianos, D. Charalambides, J. Melissas, C. Hatzitheofilou, J. Da Silva, The management of penetrating injuries of the back. A prospective study of 230 patients., Ann. Surg. 207 (1988) 72–4. https://doi.org/10.1097/00000658-198801000-00014.

[7] R.L. Nelson, E. Gladman, M. Barbateskovic, Antimicrobial prophylaxis for colorectal surgery, Cochrane Database Syst. Rev. (2014). https://doi.org/10.1002/14651858.CD001181.pub4.

[8] J.P. Sharpe, L.J. Magnotti, T.C. Fabian, M.A. Croce, Evolution of the operative management of colon trauma, Trauma Surg. Acute Care Open. 2 (2017) e000092. https://doi.org/10.1136/tsaco-2017-000092.

[9] J.A. Tyler, D.R. Welling, Historical Perspectives on Colorectal Trauma Management, Clin. Colon Rectal Surg. 31 (2018) 005–010. https://doi.org/10.1055/s-0037-1602174.

[10] S. Ogilvie, Forward surgery in modern war1944 ,. (n.d.). https://scholar.google.com/scholar?q=Ogilvie+W+H+Forward+Surgery+in+Modern+War+London+Butterworth+and+Company+1944+ (accessed December 2, 2019).

[11] Office of the Surgeon General., Circular Letter No. 178, USA, 1943.

[12] J.P. WOODHALL, A. OCHSNER, The management of perforating injuries of the colon and rectum in civilian practice., Surgery. 29 (1951) 305–20. http://www.ncbi.nlm.nih.gov/pubmed/14817639 (accessed December 2, 2019).

[13] J.W. Tucker, W.P. Fey, The management of perforating injuries of the colon and rectum in civilian practice, Surgery. 35 (1954) 213–220.

https://doi.org/10.5555/uri:pii:0039606054902366.
[14] H.H. Stone, T.C. Fabian, Management of perforating colon trauma: randomization between primary closure and exteriorization., Ann. Surg. 190 (1979) 430–6. http://www.ncbi.nlm.nih.gov/pubmed/384941 (accessed April 12, 2018).
[15] C.W. CHAPPUIS, D.J. FREY, C.D. DIETZEN, T.P. PANETTA, K.J. BUECHTER, I. COHN, Management of Penetrating Colon Injuries A Prospective Randomized Trial, Ann. Surg. 213 (1991) 492. https://doi.org/10.1097/00000658-199105000-00015.
[16] R.E. Falcone, S.R. Wanamaker, S.A. Santanello, L.C. Carey, Colorectal trauma: Primary repair or anastomosis with intracolonic bypass vs. ostomy, Dis. Colon Rectum. 35 (1992) 957–963. https://doi.org/10.1007/BF02253498.
[17] R.P. Gonzalez, M.E. Falimirski, M.R. Holevar, Further evaluation of colostomy in penetrating colon injury., Am. Surg. 66 (2000) 342–6; discussion 346-7. http://www.ncbi.nlm.nih.gov/pubmed/10776870 (accessed November 21, 2019).
[18] L.S. Sasaki, R.D. Allaben, R. Golwala, V.K. Mittal, Primary repair of colon injuries: a prospective randomized study., J. Trauma. 39 (1995) 895–901. http://www.ncbi.nlm.nih.gov/pubmed/7474005 (accessed April 7, 2018).
[19] R.L. Nelson, M. Singer, Primary repair for penetrating colon injuries, Cochrane Database Syst. Rev. (2003) CD002247. https://doi.org/10.1002/14651858.CD002247.
[20] D.C. Cullinane, R.S. Jawa, J.J. Como, A.E. Moore, D.S. Morris, J. Cheriyan, O.D. Guillamondegui, S.R. Goldberg, L. Petrey, G.P. Schaefer, K.A. Khwaja, S.E. Rowell, R.R. Barbosa, G.A. Bass, G. Kasotakis, B.R.H. Robinson, Management of penetrating intraperitoneal colon injuries: A meta-analysis and practice management guideline from the Eastern Association for the Surgery of Trauma, J. Trauma Acute Care Surg. 86 (2019) 505–515. https://doi.org/10.1097/TA.0000000000002146.
[21] D.D. and K. Inaba, Colon and Rectal Trauma, in: D.V.F. Kenneth L. Mattox, Ernest E. Moore (Ed.), Trauma, Seventh Ed., Seventh Ed, McGraw-Hill Education, 2012: pp. 620–631.
[22] R.E. Falcone, L.C. Carey, Colorectal trauma, Surg. Clin. North Am. 68 (1988) 1307–1318. https://doi.org/10.1016/S0039-6109(16)44688-8.
[23] G. Tzovaras, C. Hatzitheofilou, New trends in the management of colonic trauma, Injury. 36 (2005) 1011–1015. https://doi.org/10.1016/j.injury.2004.11.020.
[24] J.Y. Cheong, A. Keshava, Management of colorectal trauma: a review, ANZ J. Surg. 87 (2017) 547–553. https://doi.org/10.1111/ans.13908.
[25] J.P. Sharpe, L.J. Magnotti, J.A. Weinberg, B.L. Zarzaur, C.P. Shahan, N.A. Parks, T.C. Fabian, M.A. Croce, Impact of location on outcome after penetrating colon injuries., J. Trauma Acute Care Surg. 73 (2012) 1428–32; discussion 1433. https://doi.org/10.1097/TA.0b013e31825bff06.
[26] M. Sartelli, E.A. Griffiths, M. Nestori, The challenge of post-operative peritonitis after gastrointestinal surgery, Updates Surg. 67 (2015) 373–381. https://doi.org/10.1007/s13304-015-0324-1.
[27] J. Bruce, Z.H. Krukowski, G. Al-Khairy, E.M. Russell, K.G.M. Park, Systematic review of the definition and measurement of anastomotic leak after gastrointestinal surgery, Br. J. Surg. 88 (2001) 1157–1168. https://doi.org/10.1046/j.0007-1323.2001.01829.x.
[28] W.M. Chambers, N.J.M. Mortensen, Postoperative leakage and abscess formation after colorectal surgery, Best Pract. Res. Clin. Gastroenterol. 18 (2004) 865–880. https://doi.org/10.1016/j.bpg.2004.06.026.
[29] T. Calandra, J. Cohen, The International Sepsis Forum Consensus Conference on Definitions of Infection in the Intensive Care Unit, Crit. Care Med. 33 (2005) 1538–1548. https://doi.org/10.1097/01.CCM.0000168253.91200.83.
[30] H.L. Evans, D.P. Raymond, S.J. Pelletier, T.D. Crabtree, T.L. Pruett, R.G. Sawyer, Tertiary Peritonitis (Recurrent Diffuse or Localized, Surg. Infect. (Larchmt). 2 (2001) 255–266.

[31] J. Ballus, J.C. Lopez-Delgado, J. Sabater-Riera, X.L. Perez-Fernandez, A.J. Betbese, J.A. Roncal, Surgical site infection in critically ill patients with secondary and tertiary peritonitis: epidemiology, microbiology and influence in outcomes, BMC Infect. Dis. 15 (2015) 304. https://doi.org/10.1186/s12879-015-1050-5.
[32] F. Bader, M. Schröder, P. Kujath, E. Muhl, H.-P. Bruch, C. Eckmann, Diffuse postoperative peritonitis -value of diagnostic parameters and impact of early indication for relaparotomy, Eur. J. Med. Res. 14 (2009) 491. https://doi.org/10.1186/2047-783X-14-11-491.
[33] T.P. Kingham, H.L. Pachter, Colonic Anastomotic Leak: Risk Factors, Diagnosis, and Treatment, J. Am. Coll. Surg. 208 (2009) 269–278. https://doi.org/10.1016/j.jamcollsurg.2008.10.015.
[34] J.L. Martinez, E. Luque-de-Leon, J. Mier, R. Blanco-Benavides, F. Robledo, Systematic Management of Postoperative Enterocutaneous Fistulas: Factors Related to Outcomes, World J. Surg. 32 (2008) 436–443. https://doi.org/10.1007/s00268-007-9304-z.
[35] M.C. Kahya, H. Derici, N. Cin, F. Tatar, Y. Peker, H. Genç, V. Deniz, E. Reyhan, [Our experience in the cases with penetrating colonic injuries]., Ulus. Travma Acil Cerrahi Derg. 12 (2006) 223–9. http://www.ncbi.nlm.nih.gov/pubmed/16850361.
[36] J.-L. Vincent, C. Ince, J. Bakker, Clinical review: Circulatory shock - an update: a tribute to Professor Max Harry Weil, Crit. Care. 16 (2012) 239. https://doi.org/10.1186/cc11510.
[37] P.R. Miller, T.C. Fabian, M.A. Croce, L.J. Magnotti, F. Elizabeth Pritchard, G. Minard, R.M. Stewart, Improving outcomes following penetrating colon wounds: application of a clinical pathway., Ann. Surg. 235 (2002) 775–81. https://doi.org/10.1097/00000658-200206000-00004.
[38] C. MacFarlane, C. Benn, Primary Closure Of Battle Wounds Of The Colon: Is It An Option For The Military Surgeon?, J. R. Army Med. Corps. 147 (2001) 179–182. https://doi.org/10.1136/jramc-147-02-12.
[39] T. Hudolin, I. Hudolin, The role of primary repair for colonic injuries in wartime, Br. J. Surg. 92 (2005) 643–647. https://doi.org/10.1002/bjs.4915.
[40] A. Vertrees, M. Wakefield, C. Pickett, L. Greer, A. Wilson, S. Gillern, J. Nelson, J. Aydelotte, A. Stojadinovic, C. Shriver, Outcomes of Primary Repair and Primary Anastomosis in War-Related Colon Injuries, J. Trauma Inj. Infect. Crit. Care. 66 (2009) 1286–1293. https://doi.org/10.1097/TA.0b013e31819ea3fc.
[41] G. Strada, L. Raad, G. Belloni, P.S. Carraro, Large bowel perforations in war surgery: one-stage treatment in a field hospital, Int. J. Colorectal Dis. 8 (1993) 213–216. https://doi.org/10.1007/BF00290309.
[42] W.J. Choi, Management of Colorectal Trauma, J. Korean Soc. Coloproctol. 27 (2011) 166. https://doi.org/10.3393/jksc.2011.27.4.166.
[43] S.M. George, T.C. Fabian, G.R. Voeller, K.A. Kudsk, E.C. Mangiante, L.G. Britt, Primary repair of colon wounds. A prospective trial in nonselected patients., Ann. Surg. 209 (1989) 728–33; 733–4. http://www.ncbi.nlm.nih.gov/pubmed/2730183%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC1494135 (accessed October 24, 2018).
[44] T.J. Curran, A.P. Borzotta, Complications of primary repair of colon injury: literature review of 2,964 cases., Am. J. Surg. 177 (1999) 42–7. https://doi.org/10.1016/s0002-9610(98)00293-1.
[45] D. Demetriades, J.A. Murray, L. Chan, C. Ordo??ez, D. Bowley, K.K. Nagy, E.E. Cornwell, G.C. Velmahos, N. Mu??oz, C. Hatzitheofilou, C.W. Schwab, A. Rodriguez, C. Cornejo, K.A. Davis, N. Namias, D.H. Wisner, R.R. Ivatury, E.E. Moore, J.A. Acosta, K.I. Maull, M.H. Thomason, D.A. Spain, Committee on Multicenter Clinical Trials. American Association for the Surgery of Trauma, Penetrating Colon Injuries Requiring Resection: Diversion or Primary Anastomosis? An AAST Prospective

Multicenter Study, J. Trauma Inj. Infect. Crit. Care. 50 (2001) 765–775. https://doi.org/10.1097/00005373-200105000-00001.
[46] N.Y. Kamwendo, M.C.M. Modiba, N.S. Matlala, P.J. Becker, Randomized clinical trial to determine if delay from time of penetrating colonic injury precludes primary repair, Br. J. Surg. 89 (2002) 993–998. https://doi.org/10.1046/j.1365-2168.2002.02154.x.
[47] J.E. Duncan, C.H. Corwin, W.B. Sweeney, J.R. Dunne, J.W. Denobile, P.W. Perdue, M.R. Galarneau, J.P. Pearl, Management of Colorectal Injuries During Operation Iraqi Freedom: Patterns of Stoma Usage, J. Trauma Inj. Infect. Crit. Care. 64 (2008) 1043–1047. https://doi.org/10.1097/TA.0b013e318047c064.
[48] M. Bortolin, L. Baldari, M.G. Sabbadini, N. Roy, Primary Repair or Fecal Diversion for Colorectal Injuries After Blast: A Medical Review, Prehosp. Disaster Med. 29 (2014) 317–319. https://doi.org/10.1017/S1049023X14000508.
[49] S. Aleksandar, R. Dejan, V. Branislav, S. Aleksandar, R. Dejan, V. Branislav, Reasons reamputation at war amputation lower leg - our, 27 (2011) 352–355.
[50] G. Öztürk, B. Aydinli, S.S. Atamanalp, F. Celebi, M.I. Yddirgan, R. Donmez, Penetrating colon injury: experience of a single centre, Acta Chir. Belg. 109 (2009) 185–190. https://doi.org/10.1080/00015458.2009.11680403.
[51] F.L. Shannon, E.E. Moore, Primary repair of the colon: when is it a safe alternative?, Surgery. 98 (1985) 851–60. http://www.ncbi.nlm.nih.gov/pubmed/4049258 (accessed December 26, 2019).
[52] D. Demetriades, D. Charalambides, D. Pantanowitz, Gunshot wounds of the colon: role of primary repair., Ann. R. Coll. Surg. Engl. 74 (1992) 381–4. http://www.ncbi.nlm.nih.gov/pubmed/1471831 (accessed October 24, 2018).
[53] P.A. O???Neill, O.C. Kirton, L.S. Dresner, B. Tortella, M.M. Kestner, Analysis of 162 Colon Injuries in Patients with Penetrating Abdominal Trauma: Concomitant Stomach Injury Results in a Higher Rate of Infection, J. Trauma Inj. Infect. Crit. Care. 56 (2004) 304–313. https://doi.org/10.1097/01.TA.0000109856.25273.07.
[54] G.C. Velmahos, P. Vassiliu, D. Demetriades, L.S. Chan, J. Murray, A. Salim, J. Sava, N. Katkhouda, T. V Berne, Wound management after colon injury: open or closed? A prospective randomized trial., Am. Surg. 68 (2002) 795–801. http://www.ncbi.nlm.nih.gov/pubmed/12356153.