Management of penetrating intraperitoneal colon injuries: A meta-analysis and practice management guideline from the Eastern Association for the Surgery of Trauma

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BACKGROUND: The management of penetrating colon injuries in civilians has evolved over the last four decades. The objectives of this meta-analysis are to evaluate the current treatment regimens available for penetrating colon injuries and assess the role of anastomosis in damage control surgery to develop a practice management guideline for surgeons.

METHODS: Using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) methodology, a subcommittee of the Practice Management Guidelines section of EAST conducted a systematic review using MEDLINE and EMBASE articles from 1980 through 2017. We developed three relevant problem, intervention, comparison, and outcome (PICO) questions regarding penetrating colon injuries. Outcomes of interest included mortality and infectious abdominal complications.

RESULTS: Thirty-seven studies were identified for analysis, of which 16 met criteria for quantitative meta-analysis and included 705 patients considered low-risk in six prospective randomized studies. Seven hundred thirty-eight patients in 10 studies undergoing damage control laparotomy and repair or resection and anastomosis (R&A) were included in a separate meta-analysis. Meta-analysis of high-risk patients undergoing repair or R&A was not feasible due to inadequate data.

CONCLUSIONS: In adult civilian patients sustaining penetrating colon injury without signs of shock, significant hemorrhage, severe contamination, or delay to surgical intervention we recommend that colon repair or R&A be performed rather than routine colostomy. In adult high-risk civilian trauma patients sustaining penetrating colon injury, we conditionally recommend that colon repair or R&A be performed rather than routine colostomy. In adult civilian trauma patients sustaining penetrating colon injury who had damage control laparotomy, we conditionally recommend that routine colostomy not be performed; instead, definitive repair or delayed R&A or anastomosis at initial operation should be performed rather than routine colostomy. (*J Trauma Acute Care Surg.* 2019;86: 505–515. Copyright © 2018 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Systematic review/meta-analysis, level III.

KEY WORDS: Colon injury; colon trauma; colon repair; penetrating abdominal trauma; damage control surgery.

Management of penetrating colon wounds has evolved over the past four decades as primary repair has become commonplace. Traditionally, most colon injuries in the civilian population were managed by colostomy.[1,2] Since the publication of several prospective randomized studies (PRS) on the subject[3–7] and Eastern Association for the Surgery of Trauma (EAST) 1998 Guidelines for the Management of Penetrating Colon Injury,[8] there has been increasing experience with colon injury repair at time of intervention. Repair avoids colostomy and its associated psychosocial stigmata, reduces morbidity from the colostomy itself (25%),[9] and obviates the costs[10] and high complication rates associated with colostomy closure.[11–15]

In 1998, EAST published a practice management guideline (PMG) for the management of penetrating colon injuries.[8] At the time, most trauma surgeons were likely to perform repair even with significant contamination.[16,17] Since this publication, larger observational studies have been reported, more patients are having resection and anastomosis (R&A), and newer techniques are being used including delayed anastomosis (DA) after damage control laparotomy (DCL) and increased implementation of resuscitation strategies limiting crystalloid use. Therefore, we have performed a systematic review and meta-analysis to develop updated evidence-based recommendations for the management of penetrating colon injuries in the adult civilian population.

Submitted: June 20, 2018, Revised: July 11, 2018, Accepted: November 11, 2018, Published online: November 21, 2018.

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This manuscript was not presented at any meeting or conference.

DOI: 10.1097/TA.0000000000002146

OBJECTIVES

This guideline has been developed using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework.[18–20] Three specific problem, intervention, comparison, and outcome (PICO) questions were addressed:

PICO Question 1: For low-risk adult civilian patients with penetrating abdominal trauma, should colon repair/R&A be performed versus colostomy to improve survival and reduce infectious complications?
PICO Question 2: For high-risk adult civilian patients with penetrating colon injury, should colon repair/R&A be performed versus colostomy to improve survival and reduce infectious complications?
PICO Question 3: For high-risk adult civilian patients requiring DCL, should repair/R&A of penetrating/blunt colon injuries be performed versus colostomy to improve survival and reduce infectious complications?

METHODS

Outcome Measures

Outcomes were chosen and rated in importance from 1 to 9, with scores from 7 to 9 representing critical outcomes. Following the Delphi consensus, mortality, anastomotic leak, and infections were considered critical outcomes. Infectious complications were defined as superficial surgical site infection, deep surgical site infection, abscess, fistula, anastomotic leak, and fascial dehiscence.

Search Strategy

With the assistance of a medical librarian, a computerized search of the National Library of Medicine, PubMed, Cochrane, and Embase databases was undertaken on April 2, 2017. English-language citations were included for the period of January 1, 1980, through April 2, 2017, using key words "colon injury," "colon trauma," "colon repair," "damage control," and "penetrating abdominal trauma.".

Review articles and case reports were excluded from examination. Studies not directly addressing penetrating colon injury, rectal injuries, and/or articles only addressing blunt colonic trauma and military-related injuries were also excluded. Of 1,055 articles identified, 37 studies were included (Fig. 1). Randomized trials, prospective and retrospective cohort studies, and case series with outcomes analyses were used to establish recommendations. These reports were categorized by quality of study design and graded according to Guyatt et al.[19] Articles were compiled by the committee chair. All selected articles were reviewed by at least two committee members.

Methodology

Forest plots were generated and treatment effects calculated for each outcome with each study weighed proportionally to the number of subjects contributed to the analysis. Heterogeneity was calculated using χ^2 (Cochran Q statistic) and quantified with I^2. I^2 values of less than 25% were considered to provide a low degree of heterogeneity; I^2 values in the 25% to 50% range were moderately heterogeneous, and values greater than 50% were indicative of high heterogeneity.[21]

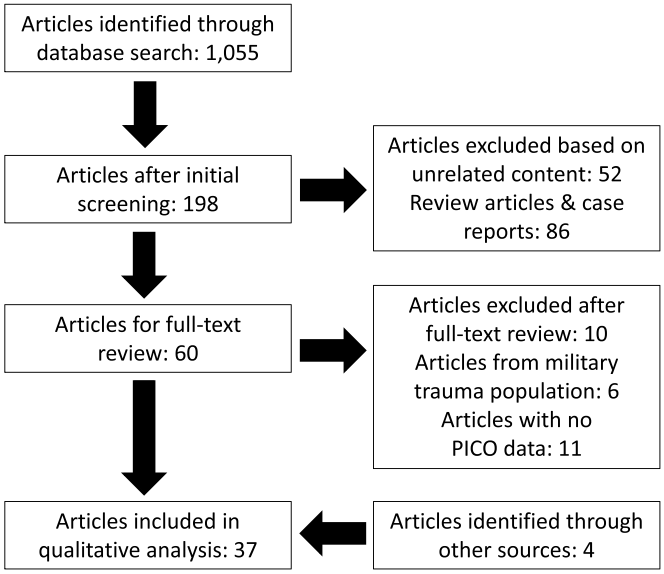

Figure 1. PRISMA flow diagram for systematic review.

Publication bias was evaluated using the Egger test[22,23]; meta-analyses were performed using STATA 15 (Stata, College Station, TX).

The GRADE framework describes four levels of evidence quality: high, moderate, low, and very low.[19,24–40] Recommendations were based on the overall quality of evidence including a risk-benefit ratio that included patients' values and preferences. Strong recommendations are prefaced by the statement, "we recommend." Weak recommendations are prefaced by the statement, "we conditionally recommend."[28–32]

RESULTS FOR COLON REPAIR/RESECTION AND ANASTOMOSIS VERSUS ROUTINE COLOSTOMY IN LOW-RISK ADULT CIVILIAN PATIENTS SUSTAINING PENETRATING TRAUMA (PICO 1)

Qualitative Synthesis

Several studies were used to formulate the 1998 EAST PMG.[3–6] In 1979, Stone and Fabian[3] enrolled 139 patients in a prospective randomized controlled trial (RCT) to compare repair with colostomy and demonstrated that repair was at least as safe as colostomy though high-risk patients (transfusion, delay, shock, contamination) were excluded from enrollment. Low-risk colon injuries were defined as destructive or non-destructive colon injuries without need for transfusion >6 units PRBC, delay to surgery, signs of shock or severe contamination. Chappius et al.[4] demonstrated that septic and infectious complications, including intra-abdominal abscess, were similar between the repair and fecal diversion groups. In 1992, Falcone et al.[5] reported outcomes in an observational study of 122 patients who underwent repair for penetrating colon injuries. At the beginning of the study, all wounds determined intra-operatively to require resection were managed with obligate end colostomy.[5] However, midway through the study, these patients had their management changed to primary anastomosis without fecal diversion.[5] Incidence of sepsis in this cohort was found to be similar to those treated earlier with end colostomy.[5]

In contrast, Sasaki et al.[6] noted a higher rate of infectious complications in the colostomy group versus primary repair/R&A in a prospective RCT of 71 patients though the authors noted that some complications were attributable to colostomy reversal.

Since the 1998 EAST PMG, two additional RCTs have been published. In a follow-up study, Gonzalez et al.[7,41] reported that patients treated with colostomy had higher rates of complications (abdominal abscess, wound dehiscence, enterocutaneous fistula, gangrenous stoma, peristomal abscess, or parastomal small bowel volvulus) than patients treated with primary repair.[41] Kamwendo et al.[42] published a trial with 238 patients randomized to repair or diversion and analyzed the effect of a delay of surgery (<12 and >12 hours) on outcomes. Patients managed with colostomy had higher rates of complications (sepsis, pulmonary complications, wound dehiscence, enterocutaneous fistula, and wound complications) regardless of surgical delay.[42] The consensus from these trials was that primary repair of penetrating colon injuries seemed to be at least as safe as fecal diversion,[3] if not safer.[4–7]

A 2003 Cochrane meta-analysis[43] comparing primary repair with colostomy, in low-risk patients, demonstrated no difference in mortality between patients undergoing primary repair versus those receiving colostomy (odds ratio (OR) for mortality, 1.22; 95% confidence interval (CI), 0.4–3.74) and demonstrated a lower rate of complications in the group managed with primary repair (OR, 0.54; 95% CI, 0.39–0.76). Specifically, the primary repair group had a lower OR of infectious complications (OR, 0.44; 95% CI, 0.17–1.1), abdominal infection (OR, 0.67; 95% CI, 0.35–1.3), and wound complications (OR, 0.73; 95% CI, 0.38–1.39) although wide confidence intervals precluded statistical significance.[43] The authors concluded that all penetrating colon injuries could be safely managed by primary repair, including R&A, and rated the evidence at Level 1B (from randomized trials).[43] Observations from retrospective studies support the conclusion that nearly all colon injuries in low-risk patients can be successfully repaired.[44–48]

Colon Resection/Anastomosis for Destructive Injuries

In 1998, available data regarding patients with destructive colon injuries (>50% of the circumference of the colon) were scarce, and the PRS available included only a small number of patients managed with R&A.[3–7] Around the time of the 1998 EAST PMG, two additional studies demonstrated concerning complication rates in patients with destructive colon injuries.[48,49] As a result, the 1998 Guideline recommended R&A for management of destructive injuries only if the patient did not have concurrent shock (systolic blood pressure (SBP) <90 mm Hg), underlying comorbid disease, significant associated injuries, penetrating abdominal trauma injury (PATI) score > 25, injury severity score (ISS) > 25, Flint grade > 11,[50] or peritonitis.[8] Destructive colon injuries alone do not necessarily qualify as high-risk colonic injuries.

In an effort to address the conflicting evidence, an American Association for the Surgery of Trauma (AAST) prospective multicenter trial was performed in 2001.[51] This study included 297 patients who were treated with colon resection; 66% of patients underwent R&A and 34% were managed with colostomy.[51] Despite including high-risk patients as defined by the 1998 Guideline, a lower mortality rate was discovered for primary anastomosis (0% versus 4%, $p = 0.012$), and no significant difference in complication rates (intra-abdominal abscess, colon leak, fascial dehiscence) were noted.[51] Although the groups were well-matched, there were higher rates of shock, colon injury severity, and PATI scores in the colostomy group.[51] The authors concluded that the surgical procedure for colon injuries did not affect mortality regardless of associated risk factors, despite some differences in the populations examined.[51]

Quantitative Synthesis (Meta-Analysis)

A total of 705 subjects with colon injury from six PRS were included in our analysis for PICO 1. Separating recommendations for repair versus R&A were not possible given limitations and variability of the current prospective studies. Analysis of pooled data demonstrated similar mortality between patients having repair/R&A versus colostomy (OR, 1.218; 95% CI, 0.40–3.74; $p = 0.73$). Regarding infections, patients having repair/R&A tended to have improved outcomes versus those who had colostomy (OR, 0.42; 95% CI, 0.17–1.03; $p = 0.059$). Heterogeneity was low for analysis of mortality ($I^2 = 0.0\%$, $p = 0.61$), and high with regard to surgical infections ($I^2 = 80.8\%$, $p < 0.001$). The data regarding mortality and infectious complications are summarized in Figure 2.

Grading the Evidence

No serious publication bias was detected for either analyzed outcome although some inconsistency was found in smaller studies. There are several prospective randomized trials that addressed this question. The overall quality of evidence is *high* (Table 1).

RECOMMENDATION

Based on the evidence, 15 of 16 authors voted in favor of a strong recommendation for colon repair or R&A in low-risk patients. Therefore, in adult civilian patients with penetrating colon injury without signs of shock, significant hemorrhage, severe contamination, or delay to surgical intervention, *we recommend* that colon repair or R&A be performed rather than colostomy.

RESULTS FOR COLON REPAIR/RESECTION AND ANASTOMOSIS VERSUS ROUTINE COLOSTOMY IN HIGH-RISK ADULT CIVILIAN PATIENTS SUSTAINING PENETRATING TRAUMA (PICO 2)

Qualitative Synthesis

High-level recommendations cannot be provided for high-risk civilian penetrating colon injuries due to confounding variables, limited population, and few prospectively designed trials. Many studies had variable inclusion of different penetrating mechanisms, namely stab wounds, gunshot wounds, and blunt traumatic injuries, that may influence risk for infectious complications.[52–55] Furthermore, differences in intra- and postoperative management of colonic injuries can alter patient risk for complications.[6,15,54,56–58] However, even with these inconsistencies, some general conclusions can be made specifically that R&A has similar complication rates to colostomy in high-risk patients, and certain patient-specific factors can

Figure 2. Forest plot of mortality and infectious complications in adult low-risk trauma patients with penetrating colon injuries.

pre-dispose patients to infectious complications regardless of procedure.

Early PRS by Chappuis et al.[4] and Gonzales et al.[41] indicated that patients with high-risk factors such as shock, hypotension (SBP < 80 mm Hg), fecal contamination, or PATI scores >25 who underwent primary repair had a similar incidence of complications as patients who underwent colostomy. These results were confirmed in the 2001 American Association for the Surgery of Trauma study,[51] as no differences in incidence of abdominal complications were noted in high-risk patients (severe fecal contamination, transfusion of >4 units blood within 24 hours, shock, delay of >6 hours to laparotomy, or PATI scores >25) who underwent R&A versus colostomy. However, in a 2015 prospective observational study by Torba et al.,[59] transfusion (OR, 1.2; 95% CI, 1.03–1.57; $p = 0.02$) and creation of a colostomy (OR, 9.1; 95% CI, 3.9–21.1; $p < 0.001$) were both independent risk factors for abdominal complications in patients with destructive colon injuries. Other factors, age, sex, mechanism of injury, hypotension, time from injury to operation, fecal contamination, colon injury severity, site of colon injury, associated injuries, and PATI, were not identified to be significant independent risk factors.

Retrospective analyses of various civilian trauma populations also have conflicting evidence regarding the effect of patient-specific factors in the development of postoperative complications, morbidity, and mortality. Adesanya et al.[54] reviewed the outcomes of 60 patients who either received R&A (right side colon wounds) or colostomy (left side colon wounds) and observed no difference in outcome (morbidity/mortality) between groups although moderate or severe fecal contamination was present in 96.7% of patients, and most patients had a delay to surgery of more than 12 hours. In a larger study, 145 patients with penetrating colon injury during two separate time periods were reviewed.[60] Only one primary repair failure occurred in the early period, and no failures occurred with R&A.[60] During the later time period, a greater percentage of patients had a higher PATI score than is generally recommended for repair, yet these patients received primary repair.[60] Patient morbidity remained at 24% regardless of procedure for both periods.[60] No significant differences in mortality were also noted by Bulger et al.[56] in a cohort of 186 patients who underwent primary repair/R&A (53%) versus colostomy (47%). In contrast, Sharpe et al.[61] observed a higher overall mortality rate in patients undergoing colostomy versus R&A for destructive injuries although colon-related mortality and morbidity were not significantly different.

At first glance, patient morbidity and development of postoperative complications seem dependent on patient-specific factors. When analyzing complication rates associated with colostomy versus R&A, Sharpe et al.[61] discovered that ISS, abdominal abbreviated injury score, and transfusion needs were significantly higher and admission SBP significantly lower in the colostomy group compared to the R&A group.[61] Although most of these destructive colon injuries could have been repaired by R&A, colostomy was recommended for patients requiring more than 6 units of blood in the first 24 hours and/or patients with significant comorbid diseases.[61] Similarly, Ozturk et al.[62] recommended stoma formation for high-risk patients (defined as severe contamination, shock, and high-grade colon injury) based on overall complication rate for 141 patients with penetrating colonic injury who received primary repair, R&A, primary repair with colostomy, or colostomy/exteriorization of the injured segment although no formal subgroup analysis was performed.

However, these patient-specific associations tend to decrease in multivariate analyses. In Bulger et al.,[56] the outcomes

TABLE 1. GRADE Recommendations

Methodology	Quality Rating
Randomized trials or double-upgrade observational studies	High
Downgraded randomized trials or upgraded observational studies	Moderate
Double-downgraded randomized trials or observational studies	Low
Triple-downgraded randomized trials, downgraded observational studies, or case series reports	Very low

of 186 patients with penetrating colon injuries were compared between two groups: 53% received primary repair/R&A and 47% received colostomy. While the total complication rate of patients requiring colostomy was significantly higher (57% vs 42%), when adjusting for ISS and hypotension, colostomy was not associated with a significant increase in total complication rate.[56] Furthermore, the incidence of abdominal abscess, wound infection, wound dehiscence, and anastomotic leak were not significantly different. Subgroup analysis indicated that development of infectious complications was related to ISS and shock, not the operation performed. Dente et al.[63] reported that PATI scores greater than 30, ISS greater than 16, transfusion of more than 2 units of blood, and a revised trauma score greater than 7.8 were all significantly associated with infections based on univariate analysis of outcomes for 311 patients with penetrating colon injuries. With multivariate logistic regression, all factors with the exception of revised trauma score had a significant association with infectious complications, and no high-risk groups were identified for whom a colostomy had fewer septic complications.[63] The authors concluded that the presence of a colostomy was associated with a greater burden of septic abdominal complications than primary repair.[63] Similarly, Girgin et al.[55] were unable to identify a high-risk group where colostomy prevented septic complications. Univariate analysis indicated that gunshot wounds, delay to operation of more than 6 hours, shock, operation duration of more than 6 hours, PATI score greater than 25, ISS greater than 20, colonic ISS greater than 3, major fecal contamination, more than two extra-abdominal injuries, transfusion greater than 4 units of blood, and colostomy were significantly associated with increased morbidity.[55] Only colostomy and transfusion remained independent factors for colon-related morbidity in subsequent multivariate regression.[55]

Contrary to Dente et al. and Girgin et al., Durham et al.[64] noted that presence of a colostomy was not associated with infection. No significant differences in wound or intra-abdominal complication rates were found among high-risk patients (PATI score >30 or colonic injury score (CIS) >4) undergoing primary repair versus colostomy although the abdominal trauma index and CIS were significantly higher in the colostomy group.[64] Further evaluation of risk factors for intra-abdominal and wound complications using stepwise regression revealed that only abdominal trauma index, CIS, and gross contamination were independent predictors of complications.[64] Therefore, repair or R&A of penetrating colon injuries should be considered in the context of patient-specific factors and colostomy may be warranted in some patients.

Quantitative Synthesis (Meta-Analysis)

Meta-analysis was not appropriate owing to heterogeneity and variability in data reporting. A summary table of available evidence for PICO 2 was created (Table 2).

Grading the Evidence

No serious publication bias was detected although some inconsistency was found in smaller studies.[58,65] Although there are prospective trials (high quality) addressing this question, most of the data are retrospective (low quality). The overall quality of evidence is *low* (Table 1).

RECOMMENDATION

Based on the evidence, 15 of 16 authors voted in favor of the following recommendation: In adult, high-risk (delay >12 hours, shock, associated injury, transfusion >6 units of blood, contamination, or left side colon injuries) trauma patients with penetrating colon injury, *we conditionally recommend* that colon repair or R&A be performed rather than mandatory colostomy. Colostomy may have a limited role in select patients.

RESULTS FOR COLON REPAIR/RESECTION AND ANASTOMOSIS VERSUS ROUTINE COLOSTOMY IN THOSE REQUIRING DCL (PICO 3)

Qualitative Synthesis

A question not addressed by the 1998 Guideline was the management of colon injuries in the setting of DCL. There are no prospective trials that specifically address this question, and available studies have conflicting recommendations. By definition, patients requiring DCL have high-risk physiology with expected higher rates of sepsis and anastomotic leak, which skew the data. Furthermore, surgeons are concerned about performing an anastomosis in DCL due to bowel edema and the negative pressure produced from temporary abdominal closure.

Initial studies suggested that R&A is safe to perform in the context of a DCL. Johnson et al.[66] reported the earliest colon R&A in the setting of DCL in 2001. Since then, management of colon injuries shifted from colostomy in all surviving DCL patients to primary repair or R&A at their institution.[66] Comparing results from the two studies, there was no statistically significant difference in abdominal septic complications. Miller et al.[67] compared DA in DCL to R&A at initial operation. Despite more severe initial shock in the DCL group, there were no anastomotic leaks in the DA group, and abscess rate and colon-related mortality were similar in both groups.[67] Chavarria-Aguilar et al.[65] reviewed destructive colon injuries in DCL over an 11-year period. The incidence of intra-abdominal abscesses were not significantly different between primary colonic repairs and diverting stomas in 104 patients requiring resection (29 requiring DCL).[65] Similarly, Ordoñez et al.[68] reported that R&A can be safely performed with DCL in patients with colon injury. Two patients in the DA group leaked versus one in the single laparotomy (SL) group ($p = 0.6$), and there was one colon-related death (DCL) in this study.[68] Combined, these studies suggest that DA during DCL is safe.

However, other studies indicate that DA with DCL is not the safest option for patients with colon trauma. Ott et al.[69] published a cohort study of 174 trauma colon resections using both damage control and immediate abdominal closure. The authors reported an "unacceptable" leak rate with DA after DCL (27%) compared to SL (6%; $p < 0.01$).[69] Unsurprisingly, the DCL group had a significantly greater length of stay (LOS), mortality, intensive care unit days, transfusion requirements, and physiologic derangement compared to the immediate repair group, as these patients were intrinsically sicker than patients receiving immediate abdominal closure.[69] Although the consequences of leak led to more complications and longer LOS, the mortality rates were not statistically different between

TABLE 2. Assessment of Available Studies for PICO 2

First Author	Year	Methods	Participants (N)	Interventions	Outcomes	Conclusions
Durham RM[64]	1997	Single-center retrospective cohort	Adults with penetrating colon injuries (N = 130)	Colostomy vs. colon repair/ resection	AL, IC	GSW = 106, SW = 14, shotgun = 9. 49 stomas (38%), 68 (52%) repair, 13 (10%) R&A with 2 leaks (15%). 49 Stoma patients had higher: PATI, blood loss, PRBC, associated injuries, contamination, hypotension. Wound infection, dehiscence, fasciitis, organ failure higher in colostomy group.
Behrman SW[57]	1998	Single-center retrospective cohort	Adults with blunt and penetrating colon injuries (N = 66)	Colostomy vs. colon repair/ R&A	AL	37 repairs (no leaks), 17 serosal tears (2 leaks), 12 R&A (1 leak). Total of 3/66 leaks (4.8%). R&A leak patient had multiple injuries and 7 units PRBC/21 liters crystalloid transfusion. No deaths. ACS associated with leak
Cornwell EE[48]	1998	Single-center prospective observational study	Adults with blunt and penetrating colon injuries (N = 56)	Colostomy vs. colon repair/R&A	AL, IC	PATI>25, >6 U PRBC, >6 hours delay. 56 patients. 8 (14.5%) had stoma. 15 (27%) intra-abdominal infections. Leak in 3 (6.1%). 2/3 patients with leak died. 1 colonic fistula. no difference L vs. R or suture vs. stapled. Intraabdominal infection rate 27%. Primary repair may be appropriate for some, leak has high mortality.
Murray JA[49]	1999	Single-center retrospective cohort	Adults with blunt and penetrating colon injuries (N = 140)	Colostomy vs. colon repair/R&A	AL, IC, L vs. R colon	R colon anastomosis had higher leak than colo-colonic (14 vs. 4%). R&A associated with complications (48% in R&A vs. 32% in colostomy) R&A can be done with the exception of PATI>25 and hypotension.
Chappuis CW[4]	1991	Single center prospective randomized trial	Adults with penetrating colon injury (N = 56)	Colostomy vs. colon repair/R&A	AL, IC	28 had repair/R&A, 28 diversion. Management of colon not influenced by associated injuries, shock, transfusion or contamination. No leaks in repair/R&A group. IC similar.
Conrad JK[60]	2000	Single-center retrospective cohort	Adults with penetrating colon injuries (N = 145)	Colostomy vs. colon repair/R&A	AL, IC, mortality	Repair or R&A 71% in early period and 87% in late period. Percent of repair identical at 59 vs. 61%. Percent of R&A increased from 12% to 26%. Morbidity was 24% in both periods. Colon related morbidity was 39% in the early period and 36% in late period. 1 repair failure, but no R&A failures. No colon-related mortality.
Dente CJ[63]	2000	Single-center retrospective cohort	Adults with penetrating colon injuries (N = 311)	Colostomy vs. Colon repair/R&A	IC	90% GSW. Risk factors for IC included PATI, ISS > 16, multiple transfusions, presence of ostomy. Colostomy does not protect from IC.
Gonzalez RP[41]	2000	Single-center prospective randomized	Adults with penetrating colon injuries (N = 176)	Colostomy vs. repair/ R&A	AL, IC	176 penetrating colon injuries. 89 repaired, 8 R&A. 16 (18%) complications. 87 colostomy, 18 (21%) complications. Hypotension in 19/89. Primary repair w/ 5 (26%) complications. Hypotension in 14/87 colostomy group with 7 (50%) complications. IC were equivalent (18% primary repair vs. 21% ostomy). No differences in complication rate with shock, fecal contamination, or PATI>25. Repair has fewer complications.
Demetriades D[51]	2001	Multi-center prospective observational study	Adults with penetrating colon injuries (N = 297)	Colostomy vs. colon repair/R&A	IC, mortality	Colon-related mortality 1.3%. 197 R&A, 100 colostomy. 97% GSW, 3% SW. DCL in 9%. Overall complications 22% in primary repair, 27% in diversion. Primary repair group: 13 leaks (6.6%). Sepsis 20% in both groups. 3 risk factors for abdominal complications: severe contamination, >4 units PRBC, and single agent antibiotic use.
Kamwendo NY[42]	2002	Single-center prospective randomized study	Adults with blunt and penetrating colon injuries (N = 240)	Colostomy vs. colon repair/R&A	AL, IC, mortality	240 patients. 120 colostomies. 191 (80%) GSW, 49 SW (20%). Patients in shock evenly matched. No difference in IC between groups. 3 R&A with no leaks. 3/117 repairs had leaks (1.3%). Time from injury to OR < 12 h vs. >12 h no differences in IC.

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Miller PR[44]	2002	Single-center retrospective cohort	Adults with blunt and penetrating colon injuries (N = 56)	Colostomy vs. Colon repair/R&A	AL, IC, mortality	56 destructive colon injuries; 40 R&A (71%), 16 colostomies (29%); 153 (73%) underwent primary repair. With pathway, abscess in 11 (27%) vs. 16 (37%). AL in 3 (7%) vs. 6 (14%). Colon related mortality 2 (5%) vs. 5 (12%). 8 deaths overall, 27% mortality with colostomy and 5% in primary anastomosis. In low-risk patients, clinical pathway decreased the number of stomas from 31% (14/45) to 9% (4/42). Conclusion: R&A should be performed regardless location, contamination, or associated injury in low-risk patients. Colostomy needed for patients with comorbidities or shock.
Bulger EM[56]	2003	Single-center retrospective cohort	Adults with penetrating colon injuries (N = 186)	Colostomy vs. R&A	AL, IC	53% R&A, 47% colostomy. Predictors of colostomy included GSW, degree of peritoneal contamination, and injury location. Predictors of intra-abdominal abscess were hypotension on admission and PATI>25. After adjusting for injury severity and hypotension, colostomy presence not associated with IC or anastomotic leak rate. IC related to ISS and hemodynamic status.
Adesanya AA[54]	2004	Single-center retrospective cohort	Adults with penetrating colon injuries (N = 60)	Colostomy vs. colon repair/R&A	Mortality, IC	"R colon injuries had repair/R&A, L colon had colostomy. Major contamination was present in 75%, moderate contamination at 21.7%, and minimal contamination, 3.3%. Complication rate: 33.3% (123 complications) in 60 patients. Complications include wound infection (56.7%), sepsis (31.7%), and EC fistula (16.7%). Patients with longer interval to repair, greater contamination, and greater degree of injury have a higher complication and higher mortality. More liberal use of primary repair recommended for penetrating injury.
Dente CJ[63]	2005	Single-center retrospective cohort	Adults with blunt and penetrating colon injuries (N = 217)	Colostomy vs. Colon repair/R&A	AL, mortality, IC	188 GSW (87%), 22 SW (10%), 7 (3%) blunt. Total of 159 suture lines: 139 repairs, 20 R&A, 65 patients had colostomy (30%). More patients diverted with left and sigmoid injuries. Stoma complications: abscess (10%) and fascial dehiscence (6%). Primary repair complications: abscess (4.5%), dehiscence (2.3%). 3/7 patients with leaks died (43%). Repair group: 4/132 leaks (3%), Resection group: 3/20 leaked (15%). Only transfusion (>9 units PRBC) was predictive of leak. Mortality similar across groups.
Girgin S[55]	2009	Single-center retrospective cohort	Adults with penetrating colon injuries (N = 196)	Colostomy vs. colon repair/R&A	AL, IC	81% GSW, 19% SW. Primary repair in 178 and 18 colostomy. Abscess in 26 (15%) of repair group, 7 (39%) stoma group. 10/178 (6%) leaks. Colostomy and transfusion >4 units were associated with higher risk of complications.
Ozturk G[62]	2009	Single-center retrospective cohort	Adults with penetrating colon injuries (N = 141)	Colostomy vs. Colon repair/R&A	AL, IC	56% repair or R&A, 36.8% with stoma, and 7% no surgery; 39.7% primary repair, 16.3% R&A; 13.4% had primary repair with stoma formation; 50.3% complication rate with 33.3% IC rate. No relationship between site of injury and septic complications. Shock significantly related to AL in R&A. Overall complication rate and IC not significantly different. Colostomy recommended for severe contamination, shock, and high injury grade.
Sharpe JP[61]	2012	Single-center retrospective cohort	Adults with blunt and penetrating colon injuries (N = 252)	Colostomy vs. Colon repair/R&A	AL, IC, mortality	Protocol: Patients with >6 units of blood or comorbidities were diverted, 3% leak rate in the remaining patients. 150 nondestructive injuries treated with repair, 102 destructive injuries (76 R&A, 26 colostomy). Comparison of current study (CS) to previous study (PS): Increased destructive injuries in CS (40% vs. 27%). Similar rate of R&A, no significant difference in: abscess, leak, or colon-related mortality. Rate of DCL in PS, 10%; CS, 18%. Leak rate for DA in patients with DCL was 11%. Decreased leak rates in CS with R&A (from 7% to 5.3%), abscess (27 vs. 18.4%), colon-related mortality (5 vs. 1.3%).
Torba M[59]	2015	Single-center prospective observational study	Adults with blunt and penetrating colon injuries (N = 157)	Colostomy vs. colon repair/R&A	AL, IC, mortality	Transfusion (>4 units) and colostomy were risk factors for IC in the less severely injured (PATI <25). AL, 4.3%.

ACS, abdominal compartment syndrome; AL, anastomotic leak; CS, current study; DA, delayed anastomosis; DC, damage control; EC, enterocutaneous; IC, infectious complications; L, left side colon injury; OR, operating room; PRBC, packed red blood cells; PS, previous study; R, right side colon injury; SW, stab wound.

patients having SL and DCL.[69] Weinberg et al.[70] published a review of 157 patients with colon injuries requiring repair, R&A, or colostomy and compared complication rates between SL and DCL. For patients requiring R&A, the DCL group had a higher incidence of complications, and colon-related complications in the DCL group were statistically higher than those in the SL group (30% vs 12%, $p < 0.01$).[70] The anastomotic leak rate was also higher in the DCL group (12% vs 3%, $p < 0.05$).[70] However, only penetrating mechanism was found to be a statistically significant risk factor for complications.[70]

The largest study to date is the Western Trauma Association's (WTA's) multi-institutional study[71] evaluating both small and large bowel anastomoses in the open abdomen. Sixty-five patients who had DA after DCL were included.[71] Eighteen percent of patients with DA had postoperative leaks, and the authors noted a progressively higher leak rate as one moved distally in the colon.[71] This study also identified risk factors associated with leak, including higher heart rate, higher base deficit at 12 hours after injury, and later time to abdomen closure, with closure after Day 5 associated with a leak rate four times higher than patients without operative delay.[71] This group recommended a cautious approach to colon R&A in DCL.[71] Similar to the WTA study, Kashuk et al.[72] reported 29 patients who underwent DA after DCL; four patients developed a leak compared to one patient in the SL group ($p < 0.01$). There were no leaks in the four patients who had colon repair with DCL.[72] In a small multi-center study, Tatebe et al.[73] examined the role of DA in DCL. Although the study is underpowered, the authors found that DCL was not associated with increased enteric leaks, entercutaneous fistula, surgical site infection, or intraperitoneal abscess.[73]

In a recent study by Anjaria et al.,[74] a higher leak rate was found in DCL patients compared to SL patients but only if the patient was unable to be closed at the first take-back operation. Similarly, the intra-abdominal abscess rate for DCL was higher than that for SL (38% vs 17%, $p < 0.01$) but only if the patient could not have the fascia closed on the first take-back operation.[74] The authors concluded that DA is safe provided the fascia is closed at the first take-back; otherwise, a stoma should be created.[74] However, they noted that multiple take-back operations are most likely a marker for a much sicker population[74] which seems consistent with the series from the WTA[71] and Georgoff et al.,[75] suggesting that if DA is to be performed, it should be done early. In summary, the literature indicates that R&A and DA with DCL is appropriate for certain populations.

Quantitative Synthesis (Meta-Analysis)

A total of 395 subjects from 10 retrospective studies were included in our analysis. Separating recommendations for repair versus R&A was not possible given limitations and variability among studies. Analysis of pooled data demonstrated similar mortality between those having repair/R&A versus colostomy (OR, 0.916; 95% CI, 0.26–3.26; $p = 0.893$). Regarding infections, patients undergoing repair/R&A showed a trend toward worse infectious complications versus those who had colostomy (OR, 1.593; 95% CI, 0.76–3.34; $p = 0.217$). Heterogeneity was high in analysis of mortality ($I^2 = 61.3\%$) and low ($I^2 = 0.0\%$) with regard to surgical infections, and no publication bias was evident for either outcome. A summary of the data for the outcomes is provided in Figure 3.

Grading the Evidence

No serious publication bias was detected for either outcome nor was there inconsistency, indirectness, or imprecision in the available studies. All studies addressing this question are retrospective. The overall quality of evidence is *very low* (Table 1).

RECOMMENDATION

While there is risk in performing an anastomosis, stoma formation is also accompanied by morbidity in patients requiring DCL. The presence of a stoma can also compromise wound management and subsequent abdominal fascial closure.[67] Nearly all available studies demonstrate that higher ISS, greater transfusion requirements, more severe physiologic derangement, and longer hospital LOS are factors for increased complication risk in DCL groups. The best outcome for DA is seen in patients

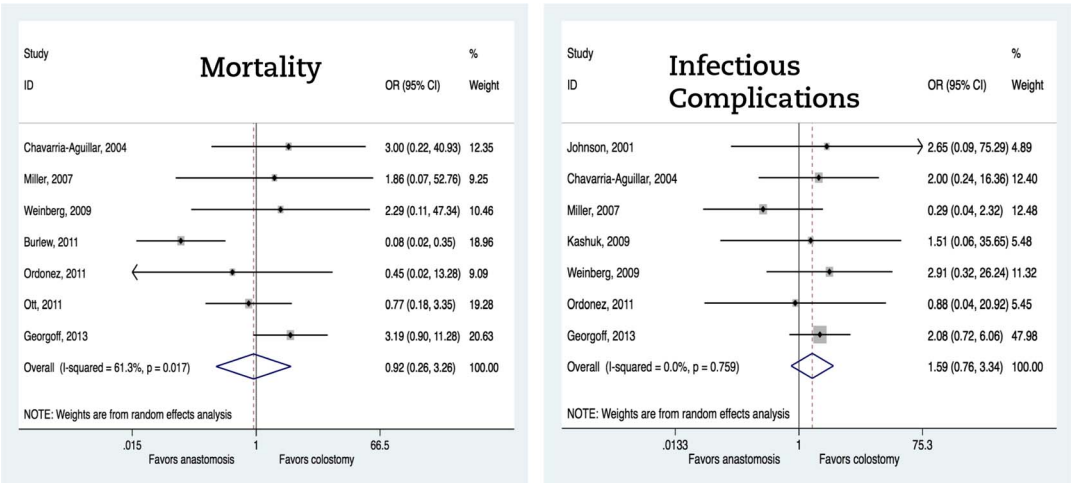

Figure 3. Forest plot of mortality and infectious complication rates in adult damage control surgery patients with colon injuries.

who resuscitate and achieve abdominal closure earlier although the quality of evidence in this area is very low.[65,68,70] Based on the literature, 10 authors voted in favor of a strong recommendation and six voted in favor of a conditional recommendation. Therefore, in adult trauma patients with penetrating colon injury who had DCL, *we conditionally recommend* that mandatory colostomy not be performed; instead, definitive repair, delayed R&A, or anastomosis (if resection already took place in the setting of DCL) may be performed rather than colostomy. Clinical judgment in these situations is paramount.

APPLYING THIS GUIDELINE TO CLINICAL PRACTICE

This PMG presents qualitative and quantitative data to formulate recommendations based on available studies on the treatment of penetrating colon injury. We recognize that every situation is different and that patient, personnel, institutional, and situational factors may warrant or require deviation from our recommendations. We encourage institutions to use this PMG to formulate their own protocols for surgically managing penetrating colon injuries.

CONCLUSION

Three evidence-based recommendations have been provided for adult civilian patients with penetrating colonic trauma. In patients without signs of shock, hemorrhage, severe contamination, or delay to surgical intervention, we recommend that colon repair or R&A be performed rather than colostomy. For high-risk patients, including those receiving DCL, *we conditionally recommend* that colon repair or R&A be performed rather than mandatory colostomy except in patients with the most severe injuries.

AUTHORSHIP

DCC and RSJ designed the study and performed PICO development, literature review, data extraction, data interpretation, manuscript development, and manuscript editing. JJC and BRHR performed PICO development, literature review, data extraction, data interpretation, manuscript development, and manuscript editing. AM performed literature review, data extraction, manuscript development, and manuscript editing. DSM, and GAB performed literature review, data extraction, data interpretation, manuscript development, and manuscript editing. JC performed data extraction, data interpretation, manuscript development, and manuscript editing. ODG designed the study and performed PICO development, literature review, data extraction, data interpretation, and manuscript editing. SRG and KAK performed literature review, data extraction, and manuscript editing. LP and RRB performed PICO development, literature review, data extraction, data interpretation, manuscript editing. GS and SER performed literature review, data extraction, data interpretation, manuscript editing. GK performed PICO development, data extraction,data interpretation, manuscript development, manuscript editing.

ACKNOWLEDGMENTS

The authors thank Emily Andreae, PhD, for assistance with manuscript editing and Brian J. Finnegan, MLIS, for assistance with the document search.

DISCLOSURE

The authors declare no conflicts of interest.
No external sources of funding were used in the preparation of this manuscript.

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