World J. Surg. 27, 632–639, 2003
DOI: 10.1007/s00268-003-6762-9

WORLD
Journal of
SURGERY

Invited Review Article

Current Management of Colon Trauma

Robert A. Maxwell, M.D.,[1] Timothy C. Fabian, M.D.[2]

[1]Department of Surgery, University of Tennessee, 979 East Third Street, Suite 401, Chattanooga, Tennessee 37403, USA
[2]Department of Surgery, University of Tennessee, 956 Court Avenue, Suite G228, Memphis, Tennessee 38163, USA

Published Online: May 2, 2003

Abstract. This article offers a comprehensive review of colon trauma from World War I to the present. The process of evidence-based medicine was used to analyze the data from the past 25 years and define standards of care in the field. Where data are less compelling, recommendations and suggestions are provided for future research. Topics highlighted include destructive and nondestructive colon injuries, rectal injuries, on-table colonic lavage, colonic bypass tubes, risk factors, perioperative antibiotics, and colostomy closure.

Management of colon trauma underwent remarkable changes during the twentieth century. Practices that were once based on limited experience and the fear of suture line failure have been replaced with superior methods that have decreased morbidity and mortality. The present management of colon trauma was scientifically established over the past 25 years, although the history of this topic dates back to World War I (WWI). This review highlights the major historical aspects of colon trauma and focuses on the current management of nondestructive and destructive colon wounds, rectal injury, the use of perioperative antibiotics, and colostomy closure.

The studies used to support the current recommendations have been selected using a Medline search of the English language since 1979 and are confined to the civilian literature. The historical background comes from review of a wide variety of sources in the surgical literature. Citations supporting current recommendations are prospective, randomized, or prospective cohort studies in most cases. Retrospective data are used to corroborate the findings of prospective studies. All recommendations herein are in agreement with the Eastern Association for the Surgery of Trauma's current Trauma Practice Guidelines. [1]

Historical Background

Wallace [2], a British military surgeon, provided the first detailed description of managing colon injury in a review of 1200 cases of gunshot wounds to the abdomen during WWI. He reported 155 isolated colon injuries of which 102 (66%) were managed by primary repair (PR). Mortality in the PR group was 50.0%, and it was 73.5% for those undergoing colostomy. Fraser [3], also a British military surgeon, and his colleague Drummond reported the use of PR for an additional 55 colon injuries during WWI with favorable results and recommended the use of PR except for the most extensive colon injuries. In that report, Fraser gave the first account of retroperitoneal sepsis secondary to colon injury for a condition that now bears his name. Thus the initial experience with managing colon injury favored PR.

Few data specifically addressing colon injury can be found during the period between WWI and WWII. Most civilian literature during this time addressed the basic utility of laparotomy for penetrating abdominal trauma [4]. High mortality rates associated with colon trauma during WWII and the lack of experience of many young military surgeons at the time led the U.S. Surgeon General [5] to mandate the routine use of colostomy in all cases of colon injury. High mortality rates seen with colon injury by the British led to a similar proclamation by Ogilvie [6]. Although a number of reports by Hurt [7], Cutler [8], Hamilton [9], Morgan [10], Mason [11], and Colcock [12] echoed the safety of colostomy for colon injury, some military surgeons continued to use PR in selected instances. Imes [13], Taylor and Thompson [4], and Gordon-Taylor [14] all reported favorable experiences with the use of PR in selected cases of colon injury during WWII. Ogilvie himself alluded to the use of PR "for small holes of the colon without peritoneal soiling" in his classic treatise [6].

The inevitable result of the wartime experience was the routine use of colostomy for colon injuries in civilian practice [8, 13, 14]. Woodhall and Ochsner at Tulane in 1951 were the first to challenge the dictum of colostomy after WWII, noting that civilian low velocity gunshot wounds and stabbings were of an entirely different nature than the high velocity devitalizing wounds seen in military combat. They reported mortality rates of 9% for PR and 40% for colostomy in a review series of 55 patients with penetrating colon injury [15]. Isaacson et al. reported further improvements in the management of colon injury at Tulane in 1961, with mortality rates of 2.05% for PR, 0% for exteriorization of the repair and 17% for colostomy in a review series of 128 patients with penetrating colon

Correspondence to: Robert A. Maxwell, M.D., e-mail: maxwelra@erlanger.org

injury [16]. In 1967 Axelrod and Hanley, also reporting from Tulane [17], showed mortality rates of 0% for PR and 9.3% for colostomy in a review of 103 patients who had sustained colon trauma.

The pioneering work from New Orleans describing selective management of colon injury stimulated increased use of this approach at other institutions. Tucker and Fey [18], Roof et al. [19], Vannix et al. [20], Wolma and Williford [21], Beall et al. [22] and Bartizal et al. [23] subsequently reported retrospective studies demonstrating favorable outcomes after selective management of colon injuries. The consensus of these reviews advocated primary repair of the colonand ushered in a new wave of prospective randomized studies that form the basis for modern management.

Colon Injury Grading Scales

Two grading scales have been devised to stratify injuries to the colon. Flint et al. first introduced a scale [24] that can be summarized as follows: grade 1: minimal contamination, minimal delay to operation, no associated injuries, and minimal shock; grade 2: through-and-through perforations or lacerations with associated injuries; and grade 3: severe tissue loss, heavy contamination, and deep shock. The American Association for the Surgery of Trauma (AAST) developed the Colon Injury Scale (CIS) [25]: grade I, serosal injury; grade II, single wall injury; grade III, < 25% wall involvement; grade IV, > 25% wall involvement; grade V, circumferential colon wall, vascular injury or both. These scales are used in the subsequent analysis of destructive and nondestructive injuries.

Nondestructive Colon Wounds

A nondestructive colon wound is an injury to the colon that is amenable to primary suture repair with limited amounts of débridement. These wounds include Flint grades 1 and 2 and CIS grades I to III. The first randomized prospective study to evaluate primary repair of such injuries was performed by Stone and Fabian in 1979 [26]. A total of 139 patients were randomized for PR or colostomy if they had an absence of shock, limited associated injury, limited fecal peritoneal soilage or delay to operation of less than 8 hours after injury. Statistically significant lower rates of intraabdominal infection occurred in the PR group (15%) versus those undergoing a colostomy (29%). There was one fecal fistula in the PR group, which healed spontaneously with local wound care. There was no mortality in this study.

Management of colon injury became progressively liberalized following Stone and Fabian's results by expanding the entry criteria for PR. Chappuis et al. [27], Sasaki et al. [28], and Gonzalez et al. [29] randomized a total of 208 patients to receive PR or colostomy irrespective of shock, contamination, time from injury, or number of associated injuries. Overall complications were similar between groups (17.1% vs. 25.7%), but a significantly decreased intraabdominal abscess rate was observed in the PR group (5.0% vs. 15.6%) (Table 1). There were no deaths attributable to the type of management employed during treatment of the colon injury and no suture line failures. In addition, there were six (5.5%) colostomy-related complications including bowel obstruction ($n = 3$), stomal prolapse ($n = 1$), stomal necrosis ($n = 1$), and peristomal abscess ($n = 1$).

George et al. [30], Demetriades et al. [31], and Ivatury et al. [32] prospectively evaluated a total of 282 patients with PR versus colostomy in a nonrandomized fashion. Reasons for stomal formation with nondestructive lesions included delayed presentation (> 24 hours), gross fecal contamination, and damage control procedures. Patients were generally not excluded for shock, blood loss, duration from injury, or number of associated injuries. Overall complication rates were 16.6% for PR and 39.1% for colostomy; the incidence of intraabdominal abscess was 5.5% for PR and 17.2% for colostomy. Three fecal fistulas occurred in the PR group, all of which healed spontaneously. There were no deaths related to the management of colon injuries [30–32].

Table 1. Comparison of primary repair and colostomy for nondestructive colon injury in prospective and prospective randomized trials.

Study	OC/PR	OC/DC	IAA/PR	IAA/DC
George [30]	22/83	6/7	10/83	1/7
Chappuis [27]	4/17	5/28	1/17	4/28
Demetriades [31]	11/76	8/24	1/76	1/24
Ivatury [32]	1/59	7/25	1/59	9/33
Sasaki [28]	5/31	10/28	1/31	5/28
Gonzalez [29]	16/89	18/87	5/89	8/87
Total	51/317 (16.1%)	53/173 (30.6%)	17/317 (5.4%)	28/173 (16.2%)

OC: overall complication rate; PR: primary repair; DC: diverting colostomy; IAA: intraabdominal abscess.

Analysis of 20 retrospective studies [33–52] of PR for colon injuries versus colostomy (2516 patients) demonstrates an overall complication rate of 14% for PR and 31% for colostomy (Table 2). Intraabdominal abscesses occurred in 5% of those who underwent PR and 12% of those with a colostomy. The suture line failure rate was 1.6% for PR and 1.3% for colostomy. Mortality was 0.11% for PR and 0.14% for colostomy when the cause of death was directly attributable to the type of repair selected.

Two centers have now reported institutional protocols in which all patients with colon injuries undergo PR regardless of injury type or associated risks [53, 54]. A total of 160 patients, including 33 with destructive colon wounds, have now had PR under these protocols. There was one fecal fistula and one anastomotic breakdown, for a leak rate of 1.3%; 12 intraabdominal abscesses (7.5%); and an overall complication rate of 61%.

When combining all prospective and retrospective studies that compared PR and colostomy for management of nondestructive colon wounds, the suture line failure rate was 1.6% for PR. The incidence of intraabdominal abscesses was 4.9% for PR and 12% for colostomy. The overall complication rate was 14% for PR and 30% for colostomy, with mortality rates of 0.11% and 0.14%, respectively. These findings clearly show the superiority of PR for nondestructive colon wounds without the morbidity associated with a colostomy.

Destructive Colon Wounds

Destructive colon wounds encompass those injuries that require segmental resection due to loss of colonic integrity or segmental devascularization due to mesenteric injury (or both). These wounds typically result from high velocity gunshot wounds or close-range shotgun blasts. Occasionally, blunt injuries from lapbelts can cause devitalizing injuries to segments of the rectosigmoid colon or cecum. These wounds include Flint grade 3 or CIS grades IV and V injuries. Management is less clear because these injuries occur less frequently and therefore less information is available.

Table 2. Comparison of primary repair and colostomy for nondestructive colon injury in retrospective series.

Study	OC/PR	OC/DC	IAA/PR	IAA/DC
Thigpen [33]	10/37	10/35	NA/37	NA/35
Wiener [34]	24/105	19/76	3/105	1/105
Karanfilian [35]	3/17	19/37	1/17	4/20
Dang [36]	5/24	3/20	NA/24	NA/20
Cook [37]	NA/5	NA/153	NA/5	NA/153
Nallathambi [38]	4/43	22/43	0	10/43
Adkins [39]	1/36	4/12	0	4/12
Shannon [40]	17/80	45/83	8/80	16/83
Dawes [41]	2/21	24/87	NA/21	NA/87
George [42]	13/73	13/31	4/73	3/31
Orsay [43]	NA/1	NA/70	NA/1	NA/70
Nelken [44]	4/34	19/39	1/34	8/39
Frame [45]	6/30	9/33	NA/30	NA/33
Levison [46]	NA/106	NA/124	5/106	15/124
Burch [47]	47/592	54/259	34/592	40/259
Morgado [48]	20/72	4/9	0	1/9
Taheri [49]	8/48	11/87	3/48	5/87
Schultz [50]	12/57	14/43	0	0
Bostick [51]	12/59	40/140	5/59	12/140
Sasaki [52]	10/102	16/52	NA/102	NA/52
Total	198/1430 (13.8%)	326/1086 (30.0%)	64/1322 (4.8%)	129/1092 (11.8%)

NA: not available.

Among reported patients with colon trauma, two prospective [31, 32] and three prospective randomized [27–29] studies identified a total of 65 patients who underwent resection and primary anastomosis (PA) for their colon injuries. The overall complication rate was 35%, and intraabdominal abscesses occurred in 23% of patients undergoing resection and PA. The leak rate was 3.1% with no associated deaths. When combined with 142 patients from 10 retrospective studies [35, 38, 40, 41, 47, 49–52, 55] that also specifically assessed resection and PA for destructive colon injuries, the overall complication rate was 36%, the intraabdominal abscess rate 19%, the leak rate 7%, and the mortality 1.7%, which was secondary to anastomotic failure.

In the largest single institution experience to date, Murray et al. retrospectively evaluated 140 destructive colon wounds, with 112 (80%) patients undergoing resection and PA and 28 (20%) undergoing colostomy [56]. There were 12 (11%) suture line failures for the resection and PA group (3 colonic fistulas and 9 anastomotic leaks), with two deaths attributable to leaks. Leaks were associated with an Abdominal Trauma Index (ATI) higher than 25 and hypotension in the emergency department. For right-sided injuries, there were fewer anastomotic complications when ileocolostomy was used than with colocolostomy.

In a landmark multicenter study, Demetriades et al. prospectively evaluated 297 patients with destructive colon injuries in which 197 underwent resection plus PA and 100 underwent diversion [57]. Patients were not randomized; rather, management of the colon wound was determined by the surgeon at exploration. Not surprisingly, patients with diversion were significantly more injured and ill than those who underwent resection and PA. Thirteen leaks (6.6%) occurred in the resection plus PA group, and there was one leak from the stump of a Hartmann's pouch. The four deaths were attributed to colon-related morbidity and abdominal sepsis, all occurring in the diversion group. The results of univariate analysis revealed that severe fecal contamination, transfusion requirement of more than 4 units, and single-agent antibiotics placed patients at greater risk for abdominal complications but not for anastomotic leakage. When controlling for all known risk factors, however, multivariate analysis demonstrated no significant difference in mortality or abdominal complications between diversion and resection plus PA. The authors therefore concluded that destructive colon injuries "should be managed by primary repair regardless of risk factors."

Table 3. Comparison of primary repair, diverting colostomy and resection, and primary anastomosis for destructive colon injuries.

Management	OC	IAA	Leak	Mortality
PR	249/1747 (14.3%)	81/1639 (4.9%)	27/1889 (1.4%)	2/1674 (0.1%)
DC	379/1259 (30.1%)	157/1265 (12.4%)	15/1385 (1.1%)	2/1518 (0.1%)
R + PA	60/165 (36.4%)	35/180 (19.4%)	15/207 (7.2%)	3/180 (1.7%)

R + PA: resection and primary anastomosis.

In summary, overall complications, intraabdominal abscess formation, the leak/colocutaneous fistula rate, and mortality are lowest for PR of nondestructive colon wounds, second lowest for colostomy due to nondestructive colon wounds, followed by resection plus PA of destructive colon wounds, and highest for colostomy for destructive colon wounds (Table 3). Factors that have been associated with anastomotic failure in patients undergoing resection and PA include co-morbid immunocompromising disorders such as diabetes mellitus, aquired immunodeficiency syndrome (AIDS), and cirrhosis and a transfusion requirement of more than six units of blood [57]. Other possible risk factors appear to be shock, significant associated injuries, and delay of operation. Patients with destructive colon injuries and any of these underlying factors traditionally would be considered for colostomy, but the latest data support more widespread use of resection and PA.

Rectal Wounds

Since WWII rectal wounds have been managed by the basic principles of proximal fecal diversion, PR of the injury when possible, and presacral drainage (PSD) [5, 6]. Only minor refinements have occurred since that time, which include the addition of distal rectal washout (DRWO) [58] and the avoidance of colostomy when PR is possible [59]. Controversies presently exist regarding the efficacy of DRWO and PSD as well as the safety associated with avoiding colostomy when the injuries are repaired. Close analysis of the available data can help clarify these issues.

After Mandell et al. [58] reported successful results with DRWO in combat casualties in the Vietnam War, four subsequent civilian studies found similarly favorable results with this technique [60–63]. Only Shannon et al. [63], however, demonstrated any statistically significant benefit from DRWO. In the largest series, reported by Burch et al. [64], and in all subsequent series [59, 65–68], no statistically significant benefit was achieved when DRWO was added to diversion and PSD when patients were evaluated for septic complications. In light of these conflicting findings, DRWO remains an option until further prospective data become available. No evidence to date suggests any harmful effects when DRWO is used. Patients with injuries similar to the combat casualties for which the technique was originally adopted with extensive rectal wall loss are probably the more appropriate candidates for DRWO.

Presacral drainage has been widely used for rectal trauma to prevent pelvic soft tissue infection. Most of the literature in this area advocates routine use of PSD in all instances of rectal injury [60, 62–66, 68, 69]. However, several authors have found no difference in the incidence of pelvic sepsis when this technique is employed [59, 61, 67]. This disparity cannot be resolved until a prospective randomized study is undertaken. In lieu of such a study, PSD should be routinely performed in all patients who have a suspected rectal injury that cannot be identified or repaired. However, if all injuries are identified and repaired (i.e., intraperitonealized by exposure through the abdomen), PSD probably adds no benefit [68].

Primary repair of rectal wounds without concomitant fecal diversion has been reported in 21 patients with no related complications [59, 65, 67, 68]. Most of these repairs were done transabdominally at the time of laparotomy. Five were done transanally for low-lying injuries without abdominal exploration [67]. The key to selecting patients who need not undergo diversion depends on the anatomy of the injury and whether the injuries can be repaired satisfactorily. Injuries along the anterior and lateral side walls of the upper two-thirds of the rectum are covered with peritoneum and are considered intraperitoneal. These injuries can be managed essentially the same as colon injuries. The distal one-third of the rectum circumferentially and the upper two-thirds of the rectum posteriorly are not covered with peritoneum and are considered extraperitoneal. Extraperitoneal injuries in the upper and middle third of the rectum can usually be dissected out without significant difficulty and repaired. However, only four such injuries are reported in the literature without concomitant diversion (none of which leaked). Therefore PR of extraperitoneal rectal injuries without fecal diversion remains an option and should be determined on a case by case basis.

Additional Management Techniques

Several other techniques have been employed in attempts to lessen the morbidity of colon injury. Prograde colonic lavage and intracolonic bypass have been used to little avail to decrease suture line leaks after PR. Prograde intraoperative lavage has been evaluated in one prospective randomized study in patients with nondestructive colon injuries [70]. With this technique, a saline infusion line is placed through the amputated appendix, and fecal effluent is drained from the rectum using corrugated tubing that has been placed through the anus.

A total of 172 patients were randomized to receive PR alone (n = 81) or prograde colonic lavage and PR (n = 91). There were four intraabdominal abscesses in the lavage group and two in the PR group. This technique has since been abandoned owing to its lack of efficacy. Results led to the same conclusion for destructive wounds.

Intracolonic bypass is used for destructive colon wounds. A soft latex tube is placed through the proximal end of the resected colon and sewn in place with absorbable sutures. The other end is brought through the distal colon and positioned at the anus. The anastomosis is then completed over the top of the tube. The net result is exclusion of the anastomosis from feces while healing occurs. The tube passes spontaneously within the first postoperative month. Two studies, one randomized prospective [71] and one prospective [72], have evaluated this technique with a total of 20 patients. There were no reported leaks or complications related to the bypass tube. There was one instance of *Clostridium difficile* colitis in a bypass patient. The number of patients is small, and meaningful conclusions cannot be drawn at this time.

Table 4. Results of exteriorization of primarily repaired colon injuries.

Study	No. exteriorized	No. leaks	No. IAA
Baker [70]	116	21	0
Thompson [74]	32	16	2
Lou [73]	50	17	0
Karanfilian [35]	18	7	NA
Dang [36]	38	10	1
Nallathambi [38]	19	6	1
Adkins [39]	8	4	0
Shannon [40]	35	0	3
Dawes [41]	16	11	3
Frame [45]	2	0	0
Levison [46]	9	5	NA
Burch [47]	83	34	NA
Bostick [51]	15	NA	1
Total	441 (100%)	131 (31%)	11 (4%)

Exteriorization of the repaired segment so the suture line can be directly observed for leakage is another technique that has been utilized in the past. One randomized [70], one prospective [73], and eleven retrospective [35, 36, 38, 40, 41, 41] studies have evaluated this technique in 441 patients (Table 4). Suture line failure occurred in 31% and intraabdominal abscess occurred in 4%. Reasons for suture line failure included leakage, obstruction, and gangrenous changes of the exteriorized segment. Exteriorizing the suture line subjects it to desiccation, luminal compromise, venous outflow obstruction, and tension, leading to excessively high failure rates. This technique currently enjoys little support.

Retained bullets or bullet fragments that have passed through the lumen of the colon are associated with an approximately 10% incidence of soft tissue infection [75]. Therefore recovery of these fragments is recommended if possible and if the patient's condition otherwise permits it.

Associated Risk Factors

A number of risk factors have been associated with increased morbidity and mortality after colon injury: hypotension or shock, interval of injury to operation, amount of fecal contamination, associated organ injury, number of transfusions, co-morbid disease. Although some of these factors may help stratify the overall risk, none has been found to increase the risk of suture line failure when PR is used for nondestructive colon injuries [29–36, 38–52, 55, 76]. Regarding destructive injuries, the risk factors for suture line failure remain controversial, with conflicting reports. The following section reviews these data in greater detail.

Perioperative shock has been shown to increase the overall incidence of postoperative complications and intraabdominal abscesses in one prospective randomized study [29] and four retrospective studies [41, 46, 48, 51] for both destructive and nondestructive colon injuries. Several retrospective studies have also reported increased mortality [35, 51] and multiple organ failure [40] when hypotension was present on admission. There must be adequate resuscitation with crystalloid fluids and blood products, and hemorrhage must be controlled to lessen the impact of shock on the outcome.

Delay of operation for 4 to 6 hours has not been shown to be a significant risk factor for nondestructive or destructive colon injury [27–29] in prospective randomized trials. In most modern-day trauma systems delays longer than 4 to 6 hours are unlikely, but

data addressing this issue are sparse. Nonetheless, delays longer than that interval in the presence of destructive injuries should be considered contraindications to resection and PA due to the potential increased risk of anastomotic failure especially in the face of large amounts of contamination or peritonitis. Patients with delays of more than 6 hours with nondestructive injuries are appropriate for PR if peritonitis has not advanced. Patients who present more than 12 hours after injury with nondestructive wounds andsevere contamination or hemodynamic instability should be assessed on an individual basis for possible diversion.

The amount of fecal contamination has been associated with an increase in septic complications and intraabdominal abscesses in four retrospective studies [30, 42, 44, 51]. However, two prospective studies that specifically assessed the amount of peritoneal contamination at the time of surgery [29, 33] showed no difference in septic complications when mild amounts (localized to the area immediately surrounding the colon wound) and moderate amounts (confined to one abdominal quadrant) of contamination were compared with severe contamination (more than one abdominal quadrant). The reason cited for improved results in these prospective studies was the use of copious irrigation with thorough cleansing of the abdominal cavity. Demetriades et al. reported a higher incidence of intraabdominal abscess with severe fecal contamination in destructive wounds but no increased risk of leakage [57]. Therefore the amount of fecal contamination alone should not influence the choice of the repair or diversion technique for any colon injury.

The number of associated organs injured, the ATI, and the Penetrating Abdominal Trauma Index (PATI) have all been associated with increased risk of both infectious and noninfectious complications [28, 30, 32, 35, 38, 40–42, 44, 46, 48, 51, 52, 55, 56]. However, like fecal contamination, the number of associated injuries, ATI, or PATI alone has not been predictive of suture line failure for any type of colon injury, destructive or nondestructive. Therefore it appears that these factors need not dictate the type of repair chosen.

Transfusion requirement has not been found to be a risk factor for suture line failure in any study evaluating nondestructive injuries. However six retrospective studies have shown transfusion requirement to increase the risk of septic and overall complication rates for all types of colon injury [30, 41, 42, 44, 48, 51]. Stewart et al., in a review of destructive colon injuries, showed that the need for more than six units of blood did increase the risk of anastomotic leak [55]. Demetriades et al. prospectively showed an increased rate of intraabdominal infection in patients receiving more than four units of blood during the first 24 hours but no increased risk of leak in destructive wounds [57]. Although still controversial, support tends to favor more liberal use of resection and primary repair, even in face of significant transfusion requirements

Perioperative Antibiotics

The use of perioperative antibiotics has been shown to be effective in reducing infectious complicationswith most types of gastrointestinal surgery. However, the literature regarding the appropriate choice has not demonstrated any agent or combination that appears superior for colon injuries. The data available clearly indicate that appropriate choices cover aerobic and anaerobic organisms with broad coverage of gram-negative species. The least expensive, most commonly available agents meeting these criteria are second-generation cephalosporins (e.g., cefoxitin), which have been shown to be effective in a number of studies [77–84]. Other appropriate choices include a β-lactam penicillin [85–88] or dual therapy with an aminoglycoside or aztreonam and a specific anaerobic agent such as clindamycin or metronidazole [80, 83, 87–94]. Use of newer broad- spectrum agents such as imipenem cilastin or "triple" antibiotics is not necessary for coverage of normal colon flora, nor is the use of these agents likely to be cost-effective.

Another pertinent area with respect to antibiotic therapy for colon injury is the duration of treatment. Some controversy appears in the literature regarding this issue. However, review of the data clearly defines 12 to 24 hours of antibiotic coverage to reduce the number of infectious complications compared to more lengthy courses of therapy. Early studies by Rowlands et al. [95] and Griswold et al. [96] advocated extended periods of antibiotic coverage (5 days), but the studies lacked a good design and have subsequently been outdated by better studies. In randomized prospective trials, Oreskovich et al. [97] and Dellinger et al. [98] reported no difference in the infectious complication rate (including intraabdominal abscesses) when antibiotics were given for 12 hours or 5 days. In a prospective randomized blinded trial, Fabian et al. [99] found similar rates of major abdominal infection (MAI) when colon wounds were treated for 24 hours or 5 days with antibiotics. Interestingly, patients with ATIs higher than 25 treated for 5 days had higher rates of MAI (30% vs. 17%) than those treated with 24 hours of antibiotics. Treatment with 24 hours of perioperative antibiotics (typically 24 hours of a second-generation cephalosporin) is now the acceptable level of care in patients with colon trauma.

Colostomy Closure

Most colostomies performed after colon injury are traditionally closed 3 months after the initial operation when the patient's general medical condition otherwise permits. Morbidity has been reported at 4.9% to 26.3% with essentially no mortality [100–109]. Berne et al. [110] reported increased complication rates in patients with colostomy closure after colonic injury (55%) than for rectal injuries (12.5%) ($p < 0.05$). They concluded that such high complication rates further supported use of resection and PA over colostomy and that diversion for extraperitoneal rectal injuries was still a good choice. Areas of present interest are early colostomy closure and whether a barium enema is necessary prior to closure.

Success with early colostomy closure during the same admission has been demonstrated by Velmahos et al. in a randomized prospective trial [100]. Altogether, 19 of their patients underwent colostomy closure during the second week after injury. A barium enema was performed prior to surgery to establish that the injury had healed. Other criteria for inclusion required that patients had to be recovering satisfactorily from their injuries, displaying healing wounds and being sepsis-free during the second week. Otherwise they were excluded from further analysis. The patients undergoing early revision were compared to 20 patients undergoing routine colostomy closure at 3 months. There were no differences in leakage rates (one in each group) or other complications. The early group reportedly was technically easier to revise than the late group owing to less adhesion formation. Early colostomy closure can therefore be considered an option in the management of colon injury after fecal diversion. Colostomy revision at 2 to 6 weeks corresponds to the period of maximum adhesion formation and should be avoided.

Crass et al. [105] and Atweh et al. [107] reported that barium enemas demonstrated no findings that changed the course of

therapy in 159 patients undergoing colostomy closure an average of 3 months after their injury. Barium enemas therefore may be considered unnecessary for general evaluation prior to colostomy closure. The exception to this policy would be patients with rectal injuries in the distal segment that could not be identified or repaired. Additionally, patients with unexplained heme-positive stool, obstructive symptoms, or other indication of problems should also have a barium enema or colonoscopy prior to colostomy closure.

Conclusions

The general principles of managing nondestructive colon trauma went full circle during the twentieth century and now clearly support the use of PR in most cases. Exceptions to the rule are patients with destructive colon injuries and associated risk factors. Risk factors for increased rates of complications or death, but not necessarily the leakage rate, have been identified as shock, duration between injury and operation, associated organ injury, transfusion requirement, and co-morbid disease. The mainstays of treating rectal injury remain diversion for extraperitoneal injuries and PSD when the injury cannot be identified or repaired. All patients requiring laparotomy for abdominal trauma should be given perioperative antibiotics. A second-generation cephalosporin for 24 hours has proved adequate. Early colostomy closure, a relatively new endeavor, is a possible option for management. Barium enema is not a mandatory part of the preoperative workup for traditional colostomy take-down procedures.

Areas that require future research include contraindications to resection and PA for destructive colon injuries and the utility of DRWO and PSD for rectal injuries. Delayed colonic anastomosis during a take-back laparotomy after a primary damage control procedure deserves investigation. Avoidance of colostomy in patients with extraperitoneal rectal injuries who undergo PRrequires further investigation. Early colostomy closure, within the first 2 weeks of injury, is an appealing technique but should undergo further evaluation before it can be considered more than an option. The answers to most of these questions require multicenter trials to accrue enough patients for statistical validity.

Résumé. Cet article offre une revue compréhensive du traumatisme du côlon depuis la première guerre mondiale jusqu'à présent. En utilisant la médecine basée sur la preuve, on a analysé les données des 25 dernières années et on a défini les standards des soins dans ce domaine. Là où les données sont moins convaincantes, les recommandations sont fournies tout comme les suggestions pour la recherche future. Les sujets abordés sont les lésions du côlon «destructives» ou «non-destructives», les lésions du rectum, la préparation colique «sur table», les stents, les facteurs de risque, les antibiotiques en période périopératoire et la fermeture des colostomies.

Resumen. El presente artículo ofrece una revisión comprensiva del trauma de colon, desde la primera guerra Mundial hasta el presente. El proceso de medicina basada en la evidencia fue utilizado en el análisis de la información correspondiente a los últimos 25 años y para definir estándares de atención. Cuando la información era menos convincente, se optó por hacer recomendaciones y sugerencias sobre futuros campos de investigación. Los tópicos de mayor preeminencia incluyen las lesiones destructivas y no destructivas del colon, las lesiones de recto, el lavado colónico en la mesa de operaciones, los tubos de "bypass" colónico, los factores de riesgo, los antibióticos perioperatorios y el cierre de la colostomía.

References

1. Cayten CG, Fabian TC, Garcia VF, et al. (1998) Patient management guidelines for penetrating colon injury. Eastern Association of the Surgery of Trauma; Trauma Practice Guidelines: http://www.east.org
2. Wallace C. A study of 1,200 cases of gunshot wounds of the abdomen. B.M.J. 1916;4:679
3. Fraser J, Drummond H. Three hundred perforating wounds of the abdomen. B.M.J. 1917;X:321
4. Taylor ER, Thompson JE. The early treatment and results thereof of injuries of the colon and rectum with 70 additional cases. Surg. Gynecol. Obstet. 1948;87:209
5. Office of the Surgeon General. Circular Letter No. 178. October 23, 1943
6. Ogilvie WH. Abdominal wounds in the Western desert. Surg. Gynecol. Obstet. 1944;78:225
7. Hurt LE. The surgical management of colon and rectal injuries in the far forward areas. Ann. Surg. 1945;122:398
8. Cutler CW. Profits to peace-time practice from surgical experiences of war. Ann. Surg. 1945;122:734
9. Hamilton JE. War wounds of the colon and rectum. N.Y. J Med 1944; 44:2706
10. Morgan CN. Wounds of the colon. Br. J. Surg. 1945;32:305
11. Mason JM. Surgery of the colon in the far forward battle area. Surgery 1945;18:534
12. Colcock BP. Traumatic perforation of the colon as seen in a general hospital. Surgery 1945;17:1
13. Imes PR. War surgery of the abdomen. Surg. Gynecol. Obstet. 1945; 81:608
14. Gordon-Taylor G. Second thoughts on the abdominal surgery of "total" war: review of 1300 cases. Br. J. Surg. 1944;32:247
15. Woodhall JP, Ochsner A. The management of perforating injuries of the colon and rectum in civilian practice. Surgery 1951;29:305
16. Isaacson JE, Buck RL, Kahle HR. Changing concepts of treatment of traumatic injuries of the colon. Dis. Colon Rectum 1961;4:811
17. Axelrod AJ, Hanley PH. Treatment of perforating wounds of the colon and rectum: a re-evaluation. South. Med. J. 1967;60:811
18. Tucker JW, Fey WP. Management of perforating injuries of the colon and rectum in civilian practice. Surgery 1954;35:213
19. Roof WR, Morris GC, De Bakey ME. Management of perforating injuries to the colon in civilian practice. Am. J. Surg. 1960;99:641
20. Vannix RS, Carter R, Hinshaw DB, et al. Surgical management of colon trauma in civilian practice. Am. J. Surg. 1963;106:364
21. Wolma FJ, Williford F. Treatment of injuries of the colon. Am. J. Surg. 1965;110:772
22. Beall AC, Bricker DL, Alessi FJ, et al. Surgical considerations in the management of civilian colon injuries. Ann. Surg. 1971;173:971
23. Bartizal JF, Boyd DR, Folk FA, et al. A critial review of the management of 392 colonic and rectal injuries. Dis. Colon Rectum 1974;17: 313
24. Flint LM, Vitale GC, Richardson JD, et al. The injured colon: relationships of management to complications. Ann. Surg. 1981;193:619
25. Moore EE, Cogbill TH, Malangoni MA, et al. Organ injury scaling. II. Pancreas, duodenum, small bowel, colon and rectum. J. Trauma 1990; 30:1427
26. Stone HH, Fabian TC. Management of perforating colon trauma: randomization between primary closure and exteriorization. Ann. Surg. 1979;190:430
27. Chappuis CW, Frey DJ, Dietzen CD, et al. Management of penetrating colon injuries: a prospective randomized trial. Ann. Surg. 1991; 213:492–497
28. Sasaki LS, Allaben RD, Golwala R, et al. Primary repair of colon injuries: a prospective randomized study. J. Trauma 1995;39:895–901
29. Gonzalez RP, Falimirski ME, Holevar MR. Further evaluation of colostomy in penetrating colon injury. Am. Surg. 2000;66:342–346
30. George SM, Fabian TC, Voeller GR, et al. Primary repair of colon

wounds: a prospective trial in nonselected patients. Ann. Surg. 1989; 209:728–734
31. Demetriades D, Charalambides D, Pantanowitz D. Gunshot wounds of the colon: role of primary repair. Ann. R. Coll. Surg. Engl. 1992;74: 381–384
32. Ivatury RR, Gaudino J, Nallathambi MN, et al. Definitive treatment of colon injuries: a prospective study. Am. Surg. 1993;59:43–49
33. Thigpen JB, Santelices AA, Hagan WV, et al. Current management of trauma to the colon. Am. Surg. 1980;46:108–110
34. Wiener I, Rojas P, Wolma FJ. Traumatic colonic perforation: review of 16 years experience. Am. J. Surg. 1981;142:717–720
35. Karanfilian RG, Ghuman SS, Pathak VB, et al. Penetrating injuries to the colon. Am. Surg. 1982;48:103–108
36. Dang CV, Peter ET, Parks SN, et al. Trauma of the colon: early drop-back of exteriorized repair. Arch. Surg. 1982;117:652–656
37. Cook A, Levine BA, Rusing T, et al. Traditional treatment of colon injuries: an effective method. Arch. Surg. 1984;119:591–594
38. Nallathambi MN, Ivatury RR, Shah PM, et al. Aggressive definitive management of penetrating colon injuries: 136 cases with 3.7 per cent mortality. J. Trauma 1984;24:500–505
39. Adkins RB, Zirkle PK, Waterhouse G. Penetrating colon trauma. J. Trauma 1984;24:491–499
40. Shannon FL, Moore EE. Primary repair of the colon: when is it a safe alternative? Surgery 1985;98:851–860
41. Dawes LG, Aprahamian C, Condon RE, et al. The risk of infection after colon injury. Surgery 1986;100:796–803
42. George SM, Fabian TC, Mangiante EC. Colon trauma: further support for primary repair. Am. J. Surg. 1988;156:16–20
43. Orsay CP, Merlotti G, Abcarian H, et al. Colorectal trauma. Dis. Colon Rectum 1989;32:188–190
44. Nelken N, Lewis F. The influence of injury severity on complication rates after primary closure or colostomy for penetrating colon trauma. Ann. Surg. 1989;209:439–447
45. Frame SB, Ridgeway CA, Rice JC, et al. Penetrating injuries to the colon: analysis by anatomic region of injury. South. Med. J. 1989;82: 1099–1102
46. Levison MA, Thomas DD, Wiencek RG, et al. Management of the injured colon: evolving practice at an urban trauma center. J. Trauma 1990;30:247–253
47. Burch JM, Martin RR, Richardson RJ, et al. Evolution of the treatment of the injured colon in the 1980s. Arch. Surg. 1991;126:979–984
48. Morgado PJ, Alfaro R, Morgado PJ, et al. Colon trauma: clinical staging for surgical decision making; analysis of 119 cases. Dis. Colon Rectum 1992;35:986–990
49. Taheri PA, Ferrara JJ, Johnson CE, et al. A convincing case for primary repair of penetrating colon injuries. Am. J. Surg. 1993;166:39–44
50. Schultz SC, Magnant CM, Richman MF, et al. Identifying the low-risk patient with penetrating colonic injury for selective use of primary repair. Surg. Gynecol. Obstet. 1993;177:237–242
51. Bostick PJ, Heard JS, Islas JT, et al. Management of penetrating colon injuries. J. Natl. Med. Assoc. 1994;86:378–382
52. Sasaki LS, Mittal V, Allaben RD. Primary repair of colon injuries: a retrospective analysis. Am. Surg. 1994;60:522–527
53. Clarke DL, Thomson SR, Muckart DJJ, et al. Universal primary colonic repair in the firearm era. Ann. R. Coll. Surg. Engl. 1999;81:58–61
54. Jacobson LE, Gomez GA, Broadie TA. Primary repair of 58 consecutive penetrating injuries of the colon: should colostomy be abandoned? Am. Surg. 1997;63:170–177
55. Stewart RM, Fabian TC, Croce MA, et al. Is resection with primary anastomosis following destructive colon wounds always safe? Am. J. Surg. 1994;168:316–319
56. Murray JA, Demetriades D, Colson M, et al. Colonic resection in trauma: colostomy versus anastamosis. J. Trauma 1999;46:250–254
57. Demetriades D, Murray JA, Chan L, et al. Penetrating colon injuries requiring resection: diversion or primary anastamosis? An AAST prospective multicenter study. J. Trauma 2001;50:765–773
58. Mandell IG, Lavenson GS, McNamara JJ. Surgical management of traumatic injuries of the colon and rectum. Arch. Surg. 1970;100:515
59. Thomas DD, Levison MA, Dykstra BJ, et al. Management of rectal injuries: dogma versus practice. Am. Surg. 1990;56:507
60. Vitale GC, Richardson JD, Flint LM. Successful management of injuries to the extraperitoneal rectum. Am. Surg. 1983;49:159
61. Mangiante EC, Graham AD, Fabian TC. Rectal gunshot wounds: management of civilian injuries. Am. Surg. 1986;52:37
62. Brunner RG, Shatney CH. Diagnostic and therapeutic aspects of rectal trauma: blunt versus penetrating. Am. Surg. 1987;53:215
63. Shannon FL, Moore EE, Moore FA, et al. Value of distal colon washout in civilian rectal trauma: reducing gut bacterial translocation. J. Trauma 1988;28:989
64. Burch JM, Feliciano DV, Mattox KL. Colostomy and drainage for civilian rectal injuries: is that all? Ann. Surg. 1989;209:600
65. Ivatury RR, Licata J, Gunduz Y, et al. Management options in penetrating rectal injuries. Am. Surg. 1991;57:50
66. Bostic PJ, Johnson DA, Heard JF, et al. Management of extraperitoneal rectal injuries. J. Natl. Med. Assoc. 1993;85:460
67. Levine JH, Longo WE, Pruitt C, et al. Management of selected rectal injuries by primary repair. Am. J. Surg. 1996;172:575
68. McGrath V, Fabian TC, Croce MA, et al. Rectal trauma: management based on anatomic distinctions. Am. Surg. 1998;64:1136
69. Trunkey D, Hays RJ, Shires GT. Management of rectal trauma. J. Trauma 1973;13:411
70. Baker LW, Thomson SR, Chadwick SJ. Colon wound management and prograde colonic lavage in large bowel trauma. Br. J. Surg. 1990; 77:872–876
71. Falcone RE, Wanamaker SR, Santanello SA, et al. Colorectal trauma: primary repair or anastomosis with intracolonic bypass vs. ostomy. Dis. Colon Rectum 1992;35:957
72. Carpenter D, Bello J, Sokol T, et al. The intracolonic bypass tube for left colon and rectal trauma: the avoidance of colostomy. Am. Surg. 1990;56:769
73. Lou MA, Johnson AP, Atik M, et al. Exteriorized repair in the management of colon injuries. Arch. Surg. 1981;116:926
74. Thompson JS, Moore EE, Moore JB. Comparison of penetrating injuries of the right and left colon. Ann. Surg. 1983;193:414
75. Poret HA, Fabian TC, Croce MA, et al. Analysis of morbidity after gunshot wounds to the colon: the missile is an adjuvant for abscess. J. Trauma 1991;32:1088
76. Ridgeway CA, Frame SB, Rice JC, et al. Primary repair vs. colostomy for the treatment of penetrating colon injuries. Dis. Colon Rectum 1989;32:1046–1049
77. Fabian TC, Hoefling SJ, Strom PR, et al. Use of antibiotic prophylaxis in penetrating abdominal trauma. Clin. Ther. 1982;5:38
78. Gentry LO, Feliciano DV, Lea S, et al. Perioperative antibiotic therapy for penetrating injuries of the abdomen. Ann. Surg. 1984;200: 561
79. Hofstetter SR, Pachter HL, Bailey AA, et al. A prospective comparison of two regimens of prophylactic antibiotics in abdominal trauma: cefoxitin versus triple drug. J. Trauma 1984;24:307
80. Nichols RL, Smith JW, Klein DB, et al. Risk of infection after penetrating abdominal trauma. N. Engl. J. Med. 1984;311:1065
81. Jones RC, Thal ER, Johnson NA, et al. Evaluation of antibiotic therapy following penetrating abdominal trauma. Ann. Surg. 1985; 201:576
82. Lou MA, Thadepalli H, Sims EH, et al. Comparison of cefamandole and carbenacillin in preventing sepsis following penetrating abdominal trauma. Am. Surg. 1985;51:580
83. Heseltine PN, Berne TV, Yellin AE, et al. The efficacy of cefoxitin versus clindamycin/gentamycin in surgically treated stab wounds of the bowel. J. Trauma 1986;26:241
84. Demetraides D, Lakhoo M, Pezikis A, et al. Short course antibiotic prophylaxis in penetrating abdominal injuries: ceftriaxone versus cefoxitin. Injury 1991;22:20

85. Moore FA, Moore EE, Mill MR. Preoperative antibiotics for abdominal gunshot wounds. Am. J. Surg. 1983–87;146:762
86. Fabian TC, Boldreghini SJ. Antibiotics in penetrating abdominal trauma. Am. J. Med. 1985;79:157
87. Moore FA, Moore EE, Ammons LA, et al. Presumptive antibiotics for penetrating abdominal wounds. Surg. Gynecol. Obstet. 1989;169:99
88. Sims EH, Lou MA, Williams SW, et al. Piperacillin monotherapy compared with metronidazole and gentamicin combination in penetrating abdominal trauma. J. Trauma 1993;34:205
89. Rowlands BJ, Ericson CD. Comparative studies of antibiotic therapy after penetrating abdominal trauma. Am. J. Surg. 1984;148:791
90. Nelson RM, Benitez PR, Newell MA, et al. Single antibiotic use for penetrating abdominal trauma. Arch. Surg. 1986;121:153
91. Posner MC, Moore EE, Harris LA, et al. Presumptive antibiotics for penetrating abdominal wounds. Surg. Gynecol. Obstet. 1987;165:29
92. Fifer T, Obeid FN, Horst HM, et al. A prospective randomized comparison of a single antibiotic (moxalactam) versus combination therapy (gentamicin and clindamycin) in penetrating abdominal trauma. Henry Ford Hosp. Med. J. 1988;36:52
93. Lou MA, Thadepalli H, Mandal AK. Safety and efficacy of mezlocillin: a single drug therapy for penetrating abdominal trauma. J. Trauma 1988;28:1541
94. Fabian TC, Hess MM, Croce MA, et al. Superiority of aztreonam/clindamycin compared with gentamicin/clindamycin in patients with penetrating abdominal trauma. Am. J. Surg. 1994;167:291
95. Rowlands BJ, Ericson CD, Fischer RP. Penetrating abdominal trauma: the use of operative findings to determine length of antibiotic therapy. J. Trauma 1987;27:250
96. Griswold JA, Muakkassa FF, Betcher E, et al. Injury severity dictates individualized antibiotic therapy in penetrating abdominal trauma. Am. Surg. 1993;59:34–39
97. Oreskovich MR, Dellinger EP, Lennard ES, et al. Duration of preventive antibiotic administration for penetrating abdominal trauma. Arch. Surg. 1982;117:200
98. Dellinger EP, Wertz MJ, Lennard ES, et al. Efficacy of short-course antibiotic prophylaxis after penetrating intestinal injury. Arch. Surg. 1986;121:23
99. Fabian TC, Croce MA, Payne LW, et al. Duration of antibiotic therapy for penetrating abdominal trauma: a prospective trial. Surgery 1992;112:788
100. Velmahos GC, Degiannis E, Wells M, et al. Early closure of colostomies in trauma patients: a prospective randomized trial. Surgery 1995;118:815–820
101. Machiedo GW, Casey KF, Blackwood JM. Colostomy closure following trauma. Surg. Gynecol. Obstet. 1980;151:58–60
102. Thal ER, Yeary EC. Morbidity of colostomy closure following colon trauma. J. Trauma 1980;20:287–291
103. Rehm CG, Talucci RC, Ross SE. Colostomy in trauma surgery: friend or foe? Injury 1993;24:595–596
104. Williams RA, Csepanyi E, Hiatt J, et al. Analysis of morbidity, mortality, and cost of colostomy closure in traumatic compared with nontraumatic colorectal diseases. Dis. Colon Rectum 1987;30:164–167
105. Crass RA, Salbi F, Trunkey DD. Colostomy closure after colon injury: a low-morbidity procedure. J. Trauma 1987;27:1237–1239
106. Sola JE, Bender JS, Buchman TG. Morbidity and timing of colostomy closure in trauma patients. Injury 1993;24:438–440
107. Atweh NA, Vieux EE, Ivatury R, et al. Indications for barium enema preceding colostomy closure in trauma patients. J. Trauma 1989;29:1641–1642
108. Livingston DH, Miller FB, Richardson JD. Are the risks after colostomy closure exaggerated? Am. J. Surg. 1989;158:17–20
109. Pachter HL, Hoballah JJ, Corcoran TA, et al. The morbidity and financial impact of colostomy closure in trauma patients. J. Trauma 1990;30:1510–1513
110. Berne JD, Velmahos GC, Chan LS, et al. The high morbidity of colostomy closure after trauma: further support for the primary repair of colon injuries. Surgery 1998;123:157–164