Adherence to a Simplified Management Algorithm Reduces Morbidity and Mortality after Penetrating Colon Injuries: A 15-Year Experience

John P Sharpe, MD, Louis J Magnotti, MD, FACS, Jordan A Weinberg, MD, FACS, Nancy A Parks, MD, George O Maish, MD, FACS, Charles P Shahan, MS, Timothy C Fabian, MD, FACS, Martin A Croce, MD, FACS

BACKGROUND: Our previous experience with colon injuries suggested that operative decisions based on a defined algorithm improve outcomes. The purpose of this study was to evaluate the validity of this algorithm in the face of an increased incidence of destructive injuries observed in recent years.

STUDY DESIGN: Consecutive patients with full-thickness penetrating colon injuries over an 8-year period were evaluated. Per algorithm, patients with nondestructive injuries underwent primary repair. Those with destructive wounds underwent resection plus anastomosis in the absence of comorbidities or large pre- or intraoperative transfusion requirements (more than 6 units packed RBCs); otherwise they were diverted. Outcomes from the current study (CS group) were compared with those from the previous study (PS group).

RESULTS: There were 252 patients who had full-thickness penetrating colon injuries: 150 (60%) patients had nondestructive colon wounds treated with primary repair and 102 patients (40%) had destructive wounds (CS). Demographics and intraoperative transfusions were similar between CS and PS groups. Of the 102 patients with destructive injuries, 75% underwent resection plus anastomosis and 25% underwent diversion. Despite more destructive injuries managed in the CS group (41% vs 27%), abscess rate (18% vs 27%) and colon-related mortality (1% vs 5%) were lower in the CS. Suture line failure was similar in CS compared with PS (5% vs 7%). Adherence to the algorithm was >90% in the CS (similar to PS).

CONCLUSIONS: Despite an increase in the incidence of destructive colon injuries, our management algorithm remains valid. Destructive injuries associated with pre- or intraoperative transfusion requirements of more than 6 units packed RBCs and/or significant comorbidities are best managed with diversion. By managing the majority of other destructive injuries with resection plus anastomosis, acceptably low morbidity and mortality can be achieved. (J Am Coll Surg 2012; 214:591–598. © 2012 by the American College of Surgeons)

Over the past century, changes in the operative management of penetrating colon injuries have produced dramatic improvements in both morbidity and mortality. Before the 20th century, colon wounds were almost uniformly fatal. Patients who did not succumb to their primary injuries ultimately died from secondary infection and sepsis after expectant management.1,2 During World War I, mortality after colon injuries fell to 60% to 75% after a paradigm shift in management: nonoperative care in the initial stages to exploration and diversion by the end of the war.3 In fact, experiences from World War II requiring diversion of all colon wounds along with improvements in triage, resuscitation, and antibiotics were associated with mortality rates falling to 22% to 35%.4,7

Through the 1970s, diversion remained the standard of care for both civilian and military colon injuries. However, trauma surgeons recognized that penetrating civilian colon injuries were different from those in their military counterparts. Civilian wounds were far less destructive and therefore were amenable to less aggressive surgical management.
This observation led to further refinement of the standard treatment of colon injuries. Primary repair was shown to be a viable alternative for nondestructive penetrating colon wounds, resulting in low morbidity.8-18

Despite continued advancements in the operative management of penetrating colon injuries, optimal management of destructive colon wounds requiring resection remains controversial. Previously, we identified a greater than 40% suture line failure rate for patients undergoing resection plus anastomosis after destructive penetrating colon injuries with pre- or intraoperative transfusion requirements of more than 6 units of packed red blood cells (PRBCs) and/or presence of significant comorbid diseases. However, otherwise healthy patients with destructive colon wounds requiring smaller transfusion requirements experienced a suture line failure rate of only 3%.19 Subsequently, we demonstrated improved outcomes for these injuries when the decision for resection and anastomosis vs diversion was based on a defined management algorithm (Fig. 1) built from those earlier identified risk factors for suture line failure.20 Since development of the algorithm, we have experienced changing injury patterns secondary to more destructive weaponry. Furthermore, the abbreviated laparotomy has become a more common practice over the last 2 decades. The purpose of this study was to evaluate the current validity of the management algorithm on outcomes after destructive penetrating colon injuries, given the rise in more devastating wounds and the more liberal use of abbreviated laparotomy.

METHODS
Identification of patients
After approval from the Institutional Review Board at the University of Tennessee Health Science Center, records of consecutive patients sustaining colon injuries over an 8-year period since the previous study20 were identified from the trauma registry of the Presley Regional Trauma Center in Memphis, TN. The charts of these patients were reviewed for data regarding patient demographics, mechanism of injury, operative management, associated injuries, and outcomes. Patients who died within 24 hours of presentation, those with rectal injuries, partial thickness injuries, and blunt injuries were excluded.

Abbreviations and Acronyms
Abd-AIS = Abdomen Abbreviated Injury Scale
CS = current study
PRBCs = packed red blood cells
PS = previous study

Figure 1. Defined management algorithm for penetrating colon injuries. PRBCs, packed red blood cells.

Definitions
Determination of destructive injuries was based on intraoperative observational criteria. Indicators of destructive colon injuries were those involving greater than 50% of the colon wall circumference, complete transection of the colon, significant loss of tissue, and devascularized segments (Table 1). All patients with nondestructive injuries underwent primary repair. Patients with destructive wounds and significant comorbidities or pre- or intraoperative transfusion requirements greater than 6 units of PRBCs were classified as high-risk and underwent diversion. The remaining patients with destructive colon injuries were classified as low-risk and underwent resection plus anastomosis (Fig. 1).

Significant medical comorbidities were defined as those medical conditions that can reduce wound healing, including chronic renal failure, congestive heart failure, HIV, cirrhosis, and patients requiring the use of chronic steroids. Complications included intra-abdominal abscess formation (de novo fluid collections with positive culture for microorganisms) and suture line failure. Colon-related mortality was defined as death secondary to one of these defined colon-related complications.

Comparison
All colon-related morbidity (abscess, suture line failure) and mortality after implementation of the management algorithm were recorded. Patients from the current study (CS) were then compared with those from the previous study (PS). Statistical analysis was performed using Student’s t-test or chi-square where appropriate. A p value < 0.05 was considered statistically significant.

RESULTS
Study population
There were 291 patients who sustained full-thickness penetrating colon injuries during the 8-year study period. Of
those, 39 early deaths were excluded. The population was 90% male, with an average age of 35 years and an average Injury Severity Score of 20. Two hundred seven (82%) patients suffered gunshot wounds, 35 (14%) had stab injuries, and 11 (4%) had shotgun wounds. Suture line failure occurred in 8 (3%) patients. Of these 252 patients, 150 (60%) patients had nondestructive injuries that were treated with primary repair. The remaining 102 (40%) patients had destructive wounds that required resection and comprise the current study group (CS).

Management

Of the remaining 102 patients in the CS, 76 (75%) underwent resection plus anastomosis and 26 (25%) underwent diversion. A comparison of the clinical characteristics of the patients receiving these 2 forms of management is demonstrated in Table 2. Patients who underwent diversion were more severely injured, with a significantly higher Injury Severity Score and Abdomen Abbreviated Injury Scale (Abd-AIS). They also experienced a significantly greater degree of shock at admission, as demonstrated by a lower admission systolic blood pressure and a larger intraoperative transfusion requirement. Patients who underwent diversion also had an overall higher mortality rate, but colon-related morbidity and mortality rates were similar to those in patients who received resection plus anastomosis.

Comparison

In order to evaluate variations in outcomes with adherence to the defined management algorithm, patients in the CS were then compared with those from the PS. Overall patient characteristics were similar between the CS and PS with respect to age (34 vs 30 years, respectively), male sex (90% vs 90%), and intraoperative PRBC transfusions (4.6 units vs 5 units, respectively). More destructive injuries were treated in the CS (40% vs 27%, \( p = 0.002 \)). Interestingly, despite more destructive injuries, resection plus anastomosis rates for destructive wounds were similar between the CS and PS groups (75% vs 71%, respectively). Colon-related outcomes are shown in Table 3. Although abscess formation, suture line failure, and colon-related mortality were all lower in the CS group, they did not reach statistical significance.

To evaluate outcomes since our original study in 1994, the trends in colon-related morbidity and mortality are demonstrated in Figure 2. A linear decrease in abscess formation from 37% in the original study to 18% in the CS was demonstrated. Furthermore, the rate of suture line failure has consistently declined, plateauing just below 5%. Colon-related mortality has also steadily decreased, from as high as 12% in the original study to 1% now.

Patients with destructive injuries were classified as high-risk, with a pre- or intraoperative transfusion requirement of more than 6 units of PRBCs and/or the presence of significant comorbid diseases. According to the management algorithm, high-risk patients require diversion. In the low-risk patients requiring resection, adherence to the algorithm decreased the proportion of patients receiving unnecessary diverting stomas from 9% (4 of 42) in the PS to 4% (3 of 72) in the CS. Of the 150 patients in the CS with nondestructive injuries receiving primary repair, 4 (2.7%) patients developed suture line failure, which was not statistically different from the 4 (5%) patients receiving resection plus anastomosis who developed suture line failure.

Table 1. Indicators of Destructive Colon Injury

| Wounds | Complete transection | Significant tissue loss | Devascularized segments |

Table 2. Comparison of Patients with Destructive Colon Injuries by Management

<table>
<thead>
<tr>
<th>Variable</th>
<th>Diversion</th>
<th>Anastomosis</th>
<th>( p ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>26</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>38</td>
<td>34</td>
<td>0.25</td>
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<tr>
<td>Injury Severity Score</td>
<td>24</td>
<td>19</td>
<td>0.01</td>
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<tr>
<td>Abd-AIS</td>
<td>3.9</td>
<td>3.5</td>
<td>0.008</td>
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<tr>
<td>Intraoperative packed RBCs, U</td>
<td>9.9</td>
<td>2.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Admission systolic blood pressure, mmHg</td>
<td>104</td>
<td>130</td>
<td>0.02</td>
</tr>
<tr>
<td>Admission base excess, mEq/L</td>
<td>(-4.3)</td>
<td>(-3.6)</td>
<td>0.67</td>
</tr>
<tr>
<td>Admission heart rate, beats/min</td>
<td>89</td>
<td>96</td>
<td>0.15</td>
</tr>
<tr>
<td>Colon-related morbidity, %</td>
<td>35</td>
<td>21</td>
<td>0.16</td>
</tr>
<tr>
<td>Colon-related mortality, %</td>
<td>8</td>
<td>1</td>
<td>0.1590</td>
</tr>
<tr>
<td>Mortality, %</td>
<td>35</td>
<td>6</td>
<td>0.0003</td>
</tr>
</tbody>
</table>

Data presented as mean values.

Abd-AIS, Abdomen Abbreviated Injury Scale.

Table 3. Comparison of Colon-Related Outcomes in Patients Undergoing Resection plus Anastomosis

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Current study</th>
<th>Previous study</th>
<th>( p ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abscess, n (%)</td>
<td>14 (18.4)</td>
<td>11 (27)</td>
<td>0.26</td>
</tr>
<tr>
<td>Suture line failure, n (%)</td>
<td>4 (5.3)</td>
<td>3 (7)</td>
<td>0.63</td>
</tr>
<tr>
<td>Colon-related mortality, n (%)</td>
<td>1 (1.3)</td>
<td>2 (5)</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Data presented as mean values.
The patient received an end-ileostomy and required an abdominal abscess with breakdown of the anastomotic suture. On day 5, the patient was noted to have fascial necrosis along with significant abdominal pain. On re-exploration, he was found to have disruption of the anastomosis. This was resected and repeated in hand-sewn fashion along with a diverting proximal stoma. The patient returned 9 months later for an uneventful planned ventral hernia repair and reversal of the ileostomy.

The last patient was a 77-year-old man with a history of diabetes, hypertension, and previous strokes, who suffered a gunshot wound resulting in a destructive wound to his splenic flexure and a concomitant injury to his stomach. The patient underwent resection of the colon injury with a stapled colo-colostomy, representing a deviation from the algorithm secondary to multiple medical comorbidities. On postoperative day 5, the patient was noted to have fascial necrosis along with significant abdominal pain. On re-exploration, he was found to have disruption of the anastomosis. This was resected and the patient underwent diversion. The patient went on to develop multiple organ failure and eventually died.

For patients who underwent resection plus anastomosis in the CS, demographics and injury characteristics were compared between those who developed suture line failure and those who did not. These data are shown in Table 4. There was no difference in age, Injury Severity Score, intraoperative transfusion requirement, and admission hemodynamics. However, patients who developed suture line failure had a higher Abdominal Abbreviated Injury Scale (Abd-AIS).

Compliance
Of the 102 destructive injuries observed in the CS, 92 patients were managed according to the clinical pathway (greater than 90% compliance with the management algorithm). This compliance is similar to that seen in the PS. Of the 92 patients who followed the pathway, 69 received resection and anastomosis. Two of these patients developed suture line breakdown, creating a suture line failure rate equivalent to that seen for low-risk patients receiving resection and anastomosis in our original study (2.9% vs 3%). Among the 10 deviations from the algorithm in our CS, 3 patients received diversion in the absence of high-risk criteria, and 7 patients
Abbreviated laparotomy and open abdomen

The use of abbreviated laparotomy with open abdomen increased from approximately 5% in the original description by Stewart and colleagues to 10% in the PS and 18% in the CS over the last 15 years (p < 0.01). In the CS, there were 27 patients with destructive colon injuries who had abbreviated laparotomy and an open abdomen. Of these, 17 (63%) underwent diversion, and 10 (37%) underwent resection and delayed anastomosis. Of these 10 patients, 2 patients had suture line failure (20%). One of these patients had delayed anastomosis but was in violation of the management algorithm. So the suture line failure rate for delayed anastomosis in patients with open abdomen and algorithm compliance was 11%.

**Table 4. Comparison of Patients Undergoing Resection plus Anastomosis With and Without Suture Line Failure**

<table>
<thead>
<tr>
<th>Variable</th>
<th>SLF</th>
<th>No SLF</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>4</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>Age, y</td>
<td>48</td>
<td>33</td>
<td>0.27</td>
</tr>
<tr>
<td>Injury Severity Score</td>
<td>27</td>
<td>19</td>
<td>0.08</td>
</tr>
<tr>
<td>Abd-AIS</td>
<td>4.5</td>
<td>3.5</td>
<td>0.002</td>
</tr>
<tr>
<td>Intraoperative packed RBCs, U</td>
<td>5.3</td>
<td>2.7</td>
<td>0.26</td>
</tr>
<tr>
<td>Admission systolic blood pressure, mmHg</td>
<td>101</td>
<td>131</td>
<td>0.08</td>
</tr>
<tr>
<td>Admission base excess, mEq/L</td>
<td>-4.0</td>
<td>-3.6</td>
<td>0.88</td>
</tr>
<tr>
<td>Admission heart rate, beats/min</td>
<td>104.3</td>
<td>96</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Data presented as mean values.

Abbreviated Injury Scale; SLF, suture line failure.

who met criteria for diversion underwent resection plus anastomosis. Of these 7 patients, 2 developed suture line breakdown, generating a 29% suture line failure rate, similar to that seen for high-risk patients receiving resection and anastomosis more than 15 years ago (42%).

DISCUSSION

Since the initial randomized clinical trial by Stone and Fabian in 1979, subsequent randomized clinical trials and prospective observational studies have demonstrated that primary repair can be successfully performed in most civilian colon injuries. However, controversy persists regarding the decision to perform an anastomosis over diversion for destructive penetrating colon injuries requiring resection. Our previous work demonstrated that patients with destructive colon injuries associated with either pre- or intraoperative transfusions greater than 6 units PRBCs and/or significant medical comorbidities were at high risk for suture line failure after resection plus anastomosis. From these findings, a defined management algorithm was developed at our institution.

Since the implementation of this clinical pathway, we have demonstrated a steady reduction in both colon-related morbidity and mortality. This clinical improvement is likely secondary to better classification of colon injuries (nondestructive vs destructive) over the last 15 years. In fact, the incidence of destructive colon injuries has increased to 40% in the CS compared with both the PS (27%) and the original study (19%). This is consistent with data from the United States Department of Justice, which showed that weaponry has evolved from small caliber revolvers to larger caliber automatic and semiautomatic pistols. Another possible explanation for the observed increase in destructive injuries in the CS is a heightened awareness of the need to manage them according to the established algorithm. That is, by better classifying these injuries, we are managing them correctly, affecting outcomes, while having little, if any, effect on compliance (unchanged from the PS). Suture line failures after resection plus anastomosis have continued to decrease and are no longer statistically different from those seen for primary repair of nondestructive wounds. Furthermore, continued adherence to the management algorithm has diminished the number of unnecessary diversions performed in low-risk patients.

Recent trauma literature has advocated the view that intraabdominal complications are not affected by the approach to colon injury management. In 2001, the American Association for the Surgery of Trauma performed a multicenter prospective trial involving 19 trauma centers and 297 patients with destructive colon injuries, two-thirds of whom were managed with resection plus anastomosis. These authors found no difference in colon-related complications (22% vs 27%, p = 0.373) between patients who underwent resection plus anastomosis and those who underwent diversion, yet they found a higher colon-related mortality in those patients who received diversion (0% vs 4%, p = 0.012). The study also noted that transfusion requirement greater than 4 units of PRBCs, severe fecal contamination, and single-agent antibiotic prophylaxis were independent risk factors for abdominal complications. The method of colon wound management (resection plus anastomosis or diversion) was not related to the development of complications. These results have recently been supported in the military literature as well. In a retrospective review of 133 patients with colon injuries from a combat theater and tertiary referral center, multivariable analysis was unable to identify independent risk factors for complications, including the management strategy. These findings are consistent with those from the current study. Although overall mortality was higher in our patients receiving diversion, colon-related complications and colon-related mortality did not differ between...
patients who underwent resection plus anastomosis and those who were diverted.

Adherence to the defined management algorithm has led to a progressive decrease in suture line failure rates from 14%\(^{19}\) to 5% in the current study. In fact, among the 4 patients who developed suture line failure, half involved deviations from the algorithm. So, with strict adherence to the algorithm for patients undergoing resection plus anastomosis, the overall suture line failure rate would have decreased to 2.7% — a rate similar to, if not less than, that reported in the current literature for elective colon resections.\(^{31-37}\)

By adhering to a proven, well-defined management algorithm, suture line failure rates for destructive penetrating colon injuries requiring resection plus anastomosis (5%) approach those for nondestructive injuries amenable to primary repair (2.7%). With the exception of a slightly higher Abd-AIS in patients with suture line failure, there were no identifiable differences between those who developed suture line failure and those who did not. Nevertheless, calculation of the Abd-AIS during emergency surgery would be cumbersome and unlikely to clearly dichotomize risk. Furthermore, suture line failure is a dreaded, but uncommon, complication. So, analysis of potential risk factors with so few patients is challenging, and may lead to flaws in data interpretation.

The decision to perform diversion in a patient with a destructive penetrating colon injury may protect against development of subsequent suture line failure, but diverting stomas expose the patient to additional complications (peristomal hernias, stomal necrosis, etc) and commit the patient to another operation. Reversal of diverting stomas has its own inherent complications that should be considered in the overall morbidity of diversion. Therefore, the surgeon should attempt to limit the number of unnecessary diversions performed whenever possible. In fact, with continued adherence to the management algorithm, our data demonstrate a more judicious use of diversion and a decrease in the proportion of low-risk patients undergoing diversion, likely limiting the number of future unnecessary stoma-related complications as well.

Although the management algorithm has proven durable over the years, it was instituted based primarily on patients who did not undergo abbreviated laparotomy with open abdomens. Miller and associates\(^{38}\) reported 11 patients who did not undergo abbreviated laparotomy with over the years, it was instituted based primarily on stomas-related complications as well.

Adherence to a defined algorithm simplified the management of destructive penetrating colon injuries. After its implementation more than 15 years ago, colon-related morbidity (abcess and suture line failure), colon-related mortality, and the number of diversions performed in low-risk patients all decreased. We believe destructive penetrating colon injuries associated with pre- or intraoperative transfusion requirement greater than 6 units PRBCs and/or the presence of significant medical comorbid diseases are best managed with diversion. By managing a majority of the other destructive colon injuries with resection plus anastomosis, an acceptably low morbidity and mortality can be achieved.

**CONCLUSIONS**

Adherence to a defined algorithm simplified the management of destructive penetrating colon injuries. After its implementation more than 15 years ago, colon-related morbidity (abcess and suture line failure), colon-related mortality, and the number of diversions performed in low-risk patients all decreased. We believe destructive penetrating colon injuries associated with pre- or intraoperative transfusion requirement greater than 6 units PRBCs and/or the presence of significant medical comorbid diseases are best managed with diversion. By managing a majority of the other destructive colon injuries with resection plus anastomosis, an acceptably low morbidity and mortality can be achieved.

**Author Contributions**

Study conception and design: Sharpe, Magnotti, Weinberg, Maish
Acquisition of data: Sharpe, Shahan, Parks
Analysis and interpretation of data: Sharpe, Magnotti, Weinberg, Fabian, Croce
Drafting of manuscript: Sharpe, Magnotti, Weinberg
Critical revision: Magnotti, Fabian, Croce

**REFERENCES**


Discussion

DR RONALD M STEWART (San Antonio, TX): Drs Sharp, Magnotti, and colleagues have reviewed their experience with respect to penetrating colon injuries and provide a simple, common-sense guideline for the management of destructive colon wounds. This work echoes the 1979 practice-changing study from Harlan Stone and Tim Fabian. Although the algorithm for managing destructive colon wounds recommended by the Memphis group is based on more than 3 decades of experience from one of the busiest trauma centers in North America, it is not without critics.

A number of small randomized trials and some larger retrospective analyses have failed to demonstrate the increased risk of anastomosis after destructive colon wounds. Some specifically recommend primary anastomosis for all of these wounds. This leads to my first question:

1. Please put this study into perspective with previous studies, specifically, the American Association for the Surgery of Trauma (AAST) multicenter study, which failed to detect any differences based on management. Should all patients regardless of injury severity have resection with anastomosis?

2. Compliance: Although this is a simple guideline with a compliance rate of 90%, which is based on a huge experience, two of the anastomotic leaks in this study were from patients in whom the protocol was not followed. Please comment on this and offer us guidance on how we can achieve improved compliance on this and other guidelines. I congratulate Drs Fabian, Croce, Magnotti,
and Sharpe for the thoughtful documentation of what is the largest evaluation of destructive colon wounds in the literature.

**DR PRESTON MILLER** (Winston-Salem, NC): Management of destructive colon injuries is a topic that continues to be widely discussed at surgical meetings as well as on morning rounds. This is a paper from a group with a long history of critically examining the management and outcomes of these injuries. These data add to that experience and demonstrate that patients managed with the described protocol who are eligible for anastomosis can expect a very low risk of leak. The paper also demonstrates that the majority of destructive colon injuries can be safely managed without stoma creation and the subsequent risks of colostomy closure. As the senior author on the paper has said once or twice, it is nice to be asked to discuss a paper that confirms your personal biases. I have a few questions:

1. Anatomic location of colon injury does not play a part in your decision. Others have suggested that this is important. Can you comment?
2. Similarly, degree of contamination is not considered in the algorithm. Why is this?
3. There are more and more data suggesting that selected patients undergoing colon resection in the setting of damage control laparotomy can safely undergo anastomosis rather than diversion after the patient’s shock, hypothermia, and hypotension have resolved. You suggest that the same decision algorithm you have described be applied in this group. Because the shock, as we can currently measure it, has resolved by this point, can you speculate why it still might play a role in the downstream decision making?

**DR LD BRITT** (Norfolk, VA): Speaking of bias, first let me state my bias. I do not believe that you should perform a protective colostomy or ileostomy if you are doing an anastomosis that you’re concerned about. If you’re that concerned about it, then obviously do a formal diversion. I would like to have the authors to provide some data to support my bias.

**DR GAGE OCHSNER** (Savannah, GA): I had the privilege of hearing this at the regional committee on trauma presentation several weeks ago, and I don’t know if it came out or not that these are not isolated colon injuries. They can include multiple other injuries. And I asked Dr Sharpe at that meeting if you have a gunshot wound in the left upper quadrant—and I don’t happen to believe that right vs left makes a difference unless it’s the left colon overlying the whole tail of the pancreas—that you have to do a partial resection on, then are you going to go ahead if you’ve lost less than 6 units of blood and perform an anastomosis on top of that, would you still put a drain there?

**DR FRANK LEWIS** (Philadelphia, PA): I would like to ask, in the resection and anastomosis group, if there was any variability in the nature and technique of the anastomosis, and specifically, how were they done? Were they hand-sewn, stapled, etc?

**DR JOHN P SHARPE** (Memphis, TN): I’ll start with Dr Stewart’s questions. In regard to other studies, specifically, the AAST trial, and their management techniques, I don’t think we can draw any firm conclusions from these other studies, especially the AAST multicenter study, as this covered 19 different centers performing 19 different management schemes for these destructive injuries. In fact, 35% of the patients from that particular study still received diversion. Our study uses one standardized algorithm from a single center over 15 years that demonstrates the lowest reported leak rate.

I’ll answer both your questions about abbreviated laparotomies in a moment, but I will first get to the issue of compliance. Compliance can be somewhat difficult in this algorithm because one part of it is completely objective. Any surgeon can count to 6 and say if the patient gets 1 more transfusion, we are going to divert this patient. The difficulty comes in obtaining the past medical history because not every patient who comes to the trauma center can speak to you; some are obtunded or even intubated. Therefore, we discover their comorbidity status after the fact, after they have already received resection and anastomosis. That’s why we’ll never be 100% compliant with this algorithm.

In regard to location and outcomes: of our 4 leaks, 2 occurred at the splenic flexure, 1 was in the proximal transverse colon, and 1 was in the ascending colon. When we stratified the injuries based on location, comparative analysis did not demonstrate any association between location of injury and development of a leak.

With respect to level of contamination, as our previous studies have demonstrated, level of contamination was not independently associated with suture line integrity. However, it is independently associated with abscess formation.

In regard to the role of our algorithm in abbreviated laparotomy: during the time period of our initial study, the abbreviated laparotomy technique was not very common. Therefore, development of this management algorithm was not intended for patients with open abdomens. However, as popularity of this technique has increased with time, management of destructive injuries in the setting of an open abdomen is something we currently deal with. Certainly, when you’re making the decision of a delayed anastomosis, additional factors do come into play, including the hemodynamic stability of the patient at that time and the character of the bowel, specifically, the level of bowel wall edema. What we have demonstrated is that use of our algorithm in patients managed with open abdomens does demonstrate a suture line failure rate that is larger than that seen in patients without open abdomens. However, it is still lower than that currently reported at most other institutions for patients undergoing abbreviated laparotomy.

Dr Britt, we had only 3 patients in our current study who received a protective diversion with an anastomosis. However, those patients were included in our diversion group.

Dr Ochsner, you made a comment on associated injuries. We did record associated injuries and found no particular association between other injuries and development of outcomes. I can tell you that if a patient met criteria to receive resection and anastomosis, and they had an injury to the splenic flexure and an associated distal pancreatectomy, I would still perform a resection and anastomosis, even after leaving a drain for the pancreas injury. However, I would try to achieve good separation between the resection line on the pancreas and our anastomosis line on the colon, probably with a healthy piece of omentum.

Dr Lewis asked how a majority of our anastomoses were performed. About 90% of the anastomoses in our current study were done with a 2-layer hand-sewn technique. Very few patients received a stapled anastomosis.