Long-term Impact of Damage Control Laparotomy

A Prospective Study

Megan Brenner, MD, MS; Grant Bochicchio, MD, MPH; Kelly Bochicchio, RN, MS; Obeid Ilahi, MD; Eduardo Rodriguez, MD, DDS; Sharon Henry, MD; Manjari Joshi, MD; Thomas Scalea, MD

Hypothesis: Damage control laparotomy (DCL) has beneficial effects on the long-term morbidity and survival of trauma patients.

Design: Prospective study.

Setting: Level I trauma center.

Patients: Eighty-eight trauma patients who were admitted during a 3-year period (January 1, 2000, through December 31, 2003) underwent damage control laparotomy and were subsequently followed up (January 1, 2001, through December 31, 2008).

Intervention: Damage control laparotomy.

Main Outcome Measures: Major and long-term complications, lengths of stay, mortality, readmissions, subsequent surgical procedures, activities of daily living, and return to work.

Results: On admission, the mean age and Injury Severity Score were 33 years and 34, respectively. Of the 88 patients, 66 (75%) were male; 46 patients had blunt injuries and 42 had penetrating injuries. Liver was the most common injury (63 patients), followed by bowel (34), spleen (33), major vessel (19), and pancreas (10). The mean admission pH and temperature were 7.19 and 34.4°C, respectively, with 21.5 U of packed red blood cells transfused. The mean (SD) number of initial abdominal operations was 4.6 (2.5) per patient, with an overall mortality of 28% (25 patients). Intensive care unit and hospital lengths of stay were 18 (15) and 32 (20) days, respectively. Of the 63 patients who survived, 58 underwent intra-abdominal closure with polyglactin mesh. During the study, 44 intra-abdominal infections and 18 enterocutaneous fistulas were diagnosed. All 63 survivors were readmitted at least once. There were a total of 186 readmissions and 92 subsequent surgical procedures. Ventral hernia repair (66 readmissions) was the most common reason for readmission, followed by infection (41) and fistula management (29). There was 0% mortality for patients who survived the preliminary hospitalization. Of the 63 surviving patients, 51 (81%) reported that they had gone back to work and resumed normal daily activities.

Conclusion: Although damage control laparotomy is associated with a significant complication and readmission rate, its overall benefit is indisputable.


The concept of damage control laparotomy (DCL) has become common in the management of seriously injured patients. Damage control laparotomy was first described in 1908 by Pringle, who used sutures over gauze packing to control portal venous hemorrhage caused by trauma. This technique was modified by Halsted in 1913, when he placed rubber sheets between the liver and the packing material to protect the hepatic parenchyma. The ensuing decades saw many advances in managing liver injuries. The consistent message conveyed by these and subsequent reports was that the success of perihepatic packing was attributable to interruption of the lethal cascade of physiological derangements.

The evolution of street warfare with the increasing use of semiautomatic weapons in the 1980s mandated surgical adaptation. Stone et al described a stepwise approach using intra-abdominal packing and abbreviated laparotomy with delayed definitive surgical management for nonhepatic trauma. Thus, for the first time, these concepts were extrapolated beyond the liver to salvage patients with multivisceral exsanguination and concomitant visceral injuries. The term “damage control” was later coined by Rotondo et al in 1992. In that landmark report, the authors described the 3 distinct phases of DCL: expeditious sur-
Eighty-eight patients underwent DCL during the study period. The mean age of the study group was 33 (12) years, with a mean ISS of 34.4 (13.0). Sixty-six patients were male (75%), with a relatively equal number of patients with blunt (46 [52%]) and penetrating (42 [48%]) injuries (Table 1). Liver was the most common solid-organ injury (n=63), followed by bowel (n=34), spleen (n=33), major vessel (n=19), and pancreas (n=10). The mean admission pH level and temperature were 7.19 (0.4) and 34.4°C (2.2°C), respectively, with an average of 21.5 U of packed red blood cells transfused within the first 24 hours of admission. The mean number of initial abdominal operations was 4.6 (2.5) per patient, with an overall initial mortality rate of 28% (25 patients). The ICU and hospital lengths of stay were 18 (15) and 32 (20) days, respectively.

Five patients underwent primary fascial closure during the first hospitalization. This represents 8% of the 63 survivors and 6% of all 88 patients. One patient required percutaneous drainage of an intra-abdominal abscess, and there were no entero-cutaneous fistulas (ECFs) or late hernias in these patients. Fifty-eight of the 63 patients who survived underwent initial abdominal closure with polyglactin mesh followed by split-thickness skin grafting (STSG). During the initial hospitalization, 44 intra-abdominal infections were diagnosed in 37 patients and 18 ECFs were diagnosed in 13 patients, for an overall infection rate of 59% and an overall ECF rate of 21%. There was 0% long-term mortality among patients who survived the preliminary hospitalization.

All 63 of the initial survivors were readmitted at least once, and their data were subsequently captured during the follow-up period (mean [SD] length of follow-up, 4.3 [3.0] years; range, 2-7 years). Additional information was obtained during clinic visits or hospital readmissions (Table 2). There were a total of 186 readmissions and 92 subsequent surgical procedures. Ventral hernia repair (66 readmissions) was the most common reason for readmission, followed by infection (41). Three patients had multiple hernia repairs. All 3 had their original hernia repaired with a biologic mesh that subsequently stretched and required a second hernia repair.
Table 2. Readmission Data on 63 Survivors After DCL

<table>
<thead>
<tr>
<th>Readmission</th>
<th>1st</th>
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<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
<th>9th</th>
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<tbody>
<tr>
<td>No. of readmissions</td>
<td>63</td>
<td>51</td>
<td>29</td>
<td>12</td>
<td>12</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Diagnosis (No. of readmissions)</td>
<td>VHR (32)</td>
<td>VHR (22)</td>
<td>Infx (17)</td>
<td>Infx (12)</td>
<td>Infx (5)</td>
<td>Infx (5)</td>
<td>Infx (2)</td>
<td>VHR (2)</td>
<td>VHR (4)</td>
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<tr>
<td>Fistula (4)</td>
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<td>Ortho (10)</td>
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<td>WC (5)</td>
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<td>LOS, mean (SD), d</td>
<td>6 (8)</td>
<td>7 (9)</td>
<td>8.2 (12)</td>
<td>17 (25)</td>
<td>10 (9)</td>
<td>9 (7)</td>
<td>12 (10)</td>
<td>9 (7)</td>
<td>5 (5)</td>
</tr>
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</table>

Abbreviations: CT, colostomy takedown; DCL, damage control laparotomy; DVT, deep venous thrombosis; Infx, infection; LOS, length of stay; Ortho, orthopedic; VHR, ventral hernia repair; WC, wound care/closure.

Most of the 41 infections diagnosed (23 [56%]) were bacteremia or line infection that most likely occurred as a result of treatment with long-term parenteral nutrition for the management of fistulas. Other infections included intra-abdominal abscess (10 [24%]). All were treated with image-guided drainage. We also diagnosed 5 wound infections (12%) and 3 other infections in (7%). Other reasons for readmission included fistula management (29 readmissions), as well as a variety of orthopedic procedures. Approximately half of the 29 readmissions for ECF were for wound care management. All 13 patients with ECF underwent takedown, and 2 patients had more than 1 takedown after recurrence of ECF. The 15 ECF takedowns are also included in the ventral hernia repair statistics because both procedures were performed during the same operation.

When stratified by mechanism of injury, patients who sustained blunt injuries were significantly older (P < .05) and had a significantly higher ISS (P < .05) (Table 1). In addition, patients with penetrating injuries (penetrating injury group) had a significantly higher survival rate (38 patients [90%]) compared with those with blunt injuries (blunt injury group) (25 [54%]). Furthermore, the rates of infections for patients in the blunt and penetrating injury groups were 72% (33 patients) and 48% (20 patients), respectively, whereas ECF occurred in 8 (17%) and 5 (12%) of the patients in the blunt and penetrating injury groups, respectively.

With regard to long-term functional ability, 51 of the 63 surviving patients (81%) reported that they had gone back to work and resumed baseline ADLs by 3 years after the injury. However, 6 patients (10%) were able to perform all ADLs but had not returned to work. These patients had yet to be cleared by physical and occupational therapy consultants for ADLs. All of these patients had persistent cognitive defects secondary to traumatic brain injury (TBI). The average Glasgow Coma Scale score on admission was 8 for the patients with residual neurologic deficits, far below the overall group average Glasgow Coma Scale score of 11.

**COMMENT**

Since its earliest description, DCL has become a tool that is increasingly used in the armamentarium of a busy trauma center. A better understanding has evolved regarding the critical role of resuscitative efforts in the management and prevention of the lethal triad of hypothermia, acidosis, and coagulopathy. Damage control laparotomy has 3 separate entities, each with its own goal. First and foremost is an abbreviated initial surgery that includes rapid control and packing of hemorrhage and control of contamination to minimize coagulopathy and avoid irreversible physiologic consequences. The second phase consists of resuscitation after temporary abdominal closure and transfer to an ICU. The third phase encompasses definitive treatment of injuries, and, if possible, abdominal closure, which is performed once a stable physiological state has been restored. The indications for DCL are well described. Variables include surgeon experience and judgment, as well as the severity and duration of hypothermia, hypotension, coagulopathy, and acidosis.

Table 3 demonstrates a direct comparison of our patients with previous reports on outcomes after DCL from Rotondo et al and Johnson et al. The patients in all 3 studies were similar with regard to age, ISS, and sex. In addition, there were many similarities among the groups regarding physiological factors at presentation, reflecting a population that is hypothermic, acidic, and coagulopathic. Our overall survival rate was 72%, but we included patients with blunt and penetrating injuries, which is different from the other 2 studies. Therefore, we further stratified our patients by mechanism of injury and compared those who sustained penetrating trauma with those who sustained blunt trauma.

As expected, ISS and age were significantly greater in the blunt injury group (Table 1). In the penetrating injury group, survival was similar (90%) to that of the patients in the recent study by Johnson et al. The overall survival in the blunt injury group was significantly lower (54%) compared with patients in the penetrating injury group. This was not unexpected given the full-body, high energy transference typically sustained by patients during blunt trauma and the multisystem organ failure, which accounted for the high mortality during the initial hospitalization. Infection rates were also higher in the blunt injury group (33 [72%]) compared with patients with penetrating injuries (20 [48%]), also contributing to the higher mortality in this population.

Patients who sustained blunt trauma had a 30% incidence of TBI (14 of 46 patients), which also contributed to their overall survival rate. Of the 12 patients in this study...
who had not returned to work by the end of the study period, 6 (50%) had TBI, which directly affected their long-term outcome and prevented them from resuming their baseline ADLs. It is hoped that further follow-up will show eventual recovery and a return to work in these patients. Both survival and long-term functional outcomes are affected by the mechanism of injury and by the presence or absence of TBI.

Most of the patients in our study underwent abdominal closure with polyglactin mesh and subsequent STSG before leaving the hospital. This technique of abdominal closure is associated with an increased risk of ECF formation. Recent studies on abdominal closure in the open abdomen after trauma report an overall ECF rate of 7% to 8%, which is much lower than the rate in the present study. However, those studies were not limited to patients undergoing DCL.

Fischer et al\(^a\) examined the ECF rate in patients who underwent DCL and found a similar rate of 8%—again, lower than that in our study—among a comparable patient population. Those authors outline a process of polyglactin mesh placement if primary closure is not possible, followed by mesh removal and STSG placement in 2 to 3 weeks, once granulation tissue has formed. Nearly 70% of ECFs (20 of 29) occurred when the mesh was covering the wound at the time of STSG placement, a practice common at our institution. Fabian\(^b\) describes similar findings with an ECF rate of 8.4%, with 71% of ECFs occurring after mesh insertion but before skin grafting. This difference in technique may explain our higher ECF rate. We have subsequently modified our technique stressing early coverage of the open abdomen to try to minimize ECF formation. Various techniques have been described to increase the incidence of primary fascial closure, which should decrease the rate of ECF formation.\(^a\)\(^b\) Cohren et al\(^c\) reported up to a 100% fascial approximation in an average of 7.5 days in a small cohort of patients undergoing sequential abdominal closure using a modified vacuum-assisted closure technique. Although primary closure would likely reduce the morbidity and mortality associated with an open abdomen, we have not found this to be feasible because of profound visceral edema and the physiological state of our patients. Some of this may be due to our resuscitation strategies. No one would consider an ECF a good outcome. However, there are no good trials suggesting that long-term outcomes with primary closure are superior to those of a multistaged approach to the open abdomen, nor are there any data reporting good long-term outcomes in patients who were closed primarily.

Achieving primary fascial closure early after DCL generally involves putting progressive tension on the fascial edges to mobilize them to the midline. This potentially weakens the fascia, which could predispose the patient to later hernia formation. An alternative is to perform complex reconstructive procedures, such as component separation, during the first admission. This procedure weakens the lateral portions of the abdominal wall, which may also lead to later hernia formation. Finally, any of these procedures will be performed when the patient is catabolic and is not in optimal nutritional shape. Based on our data, it seems that ECF can be avoided if the abdomen is closed primarily during the first hospitalization. Five patients in our series were closed primarily, and none developed an ECF. Rates of ECF may also be reduced by early closure and STSG after mesh removal. Other factors, such as nutrition, amount of bowel exposed, and length of time of exposure, may also decrease the occurrence of ECF, but to our knowledge, no randomized controlled trials are available to provide evidence that controlling these factors will avoid ECF formation. Thus, although primary fascial closure is attractive and was effective in a small number of patients in our series, we simply do not know the long-term outcomes, particularly those for hernia formation.

The most common reason for the first readmission was elective ventral hernia repair. Within 24 months of injury, 31 patients (approximately half) had completed definitive fistula repairs, if needed, with abdominal wall closure. This percentage increased to 100% by the end of year 3. No patient was left with a fistula. We generally delay definitive abdominal wall reconstruction by at least 6 months to allow for resolution of all inflammatory changes. Most of our study population underwent abdominal reconstruction in conjunction with component separation techniques that included placement of a biologic mesh (ie, AlloDerm [LifeCell Corporation, Branchburg, New Jersey] or FlexHD [Ethicon, Inc, Edison, New Jersey]) and were performed by plastic surgeons. Our recurrence rate of 5% seems quite good and is comparable to the rate found in other studies.\(^21\) In fact, the hernias may have been related more to our choice of mesh, because we have found that biologic mesh commonly stretches when used as the only fascial substitute.\(^20\)

The goal of this study was to describe long-term outcomes after DCL. We followed up patients for as long as 7 years after the initial hospitalization and found some encouraging results. Despite the high rate of open abdomens after DCL, patients fared well with staged closures and had a very acceptable rate of recurrent hernia. Although all patients required readmission and reoperation, 0% mortality leaves no room for improvement.

We are fortunate that all our inpatients are seen by physical and occupational therapists. Thus, we were able

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Rotondo et al. (^a) 1993 (n=24)</th>
<th>Johnson et al. (^b) 2001 (n=21)</th>
<th>Present Study (n=88)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>30.6</td>
<td>25.6</td>
<td>33 (12)</td>
</tr>
<tr>
<td>Sex, No. M/F</td>
<td>23/1</td>
<td>21/0</td>
<td>66/22</td>
</tr>
<tr>
<td>ISS</td>
<td>24.2</td>
<td>30.4</td>
<td>34.4 (13.0)</td>
</tr>
<tr>
<td>No. (%) with penetrating injury</td>
<td>24 (100)</td>
<td>21 (100)</td>
<td>42 (48)</td>
</tr>
<tr>
<td>Temperature, °C</td>
<td>32.9</td>
<td>34.8</td>
<td>34.4 (2.2)</td>
</tr>
<tr>
<td>pH</td>
<td>7.20</td>
<td>7.18</td>
<td>7.2 (0.4)</td>
</tr>
<tr>
<td>PRBCs transfused in the first 24 h, U</td>
<td>22.7</td>
<td>11.2</td>
<td>21.5 (12.0)</td>
</tr>
<tr>
<td>Survival, No. (%)</td>
<td>14 (58)</td>
<td>19 (90)</td>
<td>63 (72)</td>
</tr>
</tbody>
</table>

Abbreviations: DCL, damage control laparotomy; ISS, Injury Severity Score; PRBCs, packed red blood cells.

\(^a\) Data are presented as mean or mean (SD) unless otherwise indicated.

Table 3. Comparison of Studies on Outcomes After DCL\(^a\)
to set an objective assessment of ability to function. Occupational and physical therapy are available at our rehabilitation facilities and are readily available in our clinic. We realize that there are many more sophisticated measures of functional performance, such as the 36-Item Short-Form Health Survey.30 We simply did not have the resources to use these more time-consuming and complicated assessment tools. Thus, we selected the ability to return to work and performance of ADLs as surrogate measures of functional performance.

The future focus should be on reducing morbidities, such as ECF and infections, as well as attempting to reduce hernia rates. We are encouraged that, other than the patients with severe TBI, all were able to return to work 3 years after injury. We hope that the few patients who were unable to perform their baseline ADLs will resume function after more time with TBI rehabilitation. The long-term survival and functional outcomes after DCL truly justify its high utilization of resources.

In conclusion, DCL continues to be an effective way of managing the severely injured trauma patient. Although this surgical approach is associated with a substantial complication and readmission rate, its long-term survival and benefit are indisputable.

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Correspondence: Megan Brenner, MD, MS, R. Adams Cowley Shock Trauma Center, University of Maryland, 22 S Greene St, Baltimore, MD 21201.


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REFERENCES

2. Halsted WS. Ligature and suture material: the employment of fine silk in preference to catgut and the advantages of transfusion of tissues and vessels in control of hemorrhage: also an account of the introduction of gloves, gutta-percha tissue and silver foil. JAMA. 1913;60(15):1119-1126.