Hypothesis: Abbreviated thoracotomy, a damage-control strategy, improves survival in patients with metabolic exhaustion.

Design: Case series report.

Setting: University-based, level I trauma center.

Patients: All patients admitted to our trauma center with severe chest trauma in whom an abbreviated thoracotomy was performed between January 1, 1994, and January 1, 1998.

Interventions: Patients in whom an abbreviated thoracotomy was performed had their life-threatening thoracic injuries treated and had temporary closure of the incision. They were then resuscitated in the intensive care unit (ICU). Definitive care of injuries and formal chest closure were performed when physiological characteristics were normalized.

Main Outcome Measures: Survival to discharge and postoperative complications.

Results: Of 10,787 patients admitted to the trauma center, 196 required thoracic operations. Eleven of these 196 patients underwent abbreviated thoracotomy; all patients survived to reach the ICU. Four died in the ICU within 24 hours of injury; the remaining 7 patients survived and were discharged. Based on their Trauma and Injury Severity Score, predicted mortality for our 11 patients was 59%; our mortality was 36%. Complications after abbreviated thoracotomy were similar to those seen after standard thoracotomy.

Conclusions: Abbreviated thoracotomy is a useful strategy in the treatment of severe chest trauma. Its use in situations of metabolic exhaustion or planned reexploration may increase patient survival rates by expediting transfer of the patient from the operating room to the ICU, where homeostasis can be restored.


Treatment of the multiple-injured trauma patient with complex injuries has evolved from a strategy that encourages surgeons to repair all identified injuries at the initial operation to one that promotes delaying the treatment of non–life-threatening injuries in patients with acidemia, hypothermia, and coagulopathy (metabolic exhaustion). In the past, many patients with these conditions died of irreversible disseminated intravascular coagulation in the operating room or shortly thereafter in the intensive care unit (ICU).1 The concept of metabolic exhaustion originated from this observation.1-3 Surgeons began delaying treatment of non–life-threatening injuries at the initial operation and transferring patients to the ICU for continued resuscitation, and the strategy of “damage control” was born.6,7 When physiological derangements are corrected, the patient is returned to the operating room for completion of the operation. The application of damage-control laparotomy in patients with severe intra-abdominal injuries is associated with improved mortality rates.8-10

Two other precepts are applied routinely to the trauma patient. The first is “second-look” laparotomy.1,5,11 Trauma surgeons routinely take patients back for a subsequent operation when marginally viable tissue is left behind or when cotton gauze is packed to promote hemostasis. The second is “temporary closure” of the abdomen.1-13 Using a prosthesis to bridge the abdominal fascia allows for multiple reexplorations of the abdomen and prevents the increasingly recognized problem of intra-abdominal hypertension and abdominal compartment syndrome.14-17

These concepts of damage control, temporary closure, and reexploration have not been routinely applied to patients with major thoracic injuries. Although recent reports have described individual adult trauma patients in whom the chest was...
materials and methods

The trauma registry at the University of California, Davis, Medical Center, Sacramento, was used to identify 196 consecutive trauma patients who had a thoracotomy from 10787 trauma patients admitted to the hospital between January 1, 1994, and January 1, 1998. Review of these 196 medical charts identified 11 patients in whom an abbreviated thoracotomy was performed. Medical records from these patients were evaluated for the reasons the chest was left open, the associated thoracic and abdominal injuries, the patient’s postoperative treatment, the time frame and variables that allowed for safe closure of the chest, the complications, and the mortality associated with this procedure.

Temporary chest closure was performed by either (1) packing the chest with gauze pads and treating the open wound; (2) closing the chest with a Silastic sheet, with or without packing; or (3) closing the skin incision alone, with or without packing. The decision to perform an abbreviated thoracotomy was made at the discretion of the attending surgeon and was based on the need for a second-look thoracotomy, the development of thoracic compartment syndrome, or the patient’s showing evidence of metabolic exhaustion. Complications were defined as follows: pneumonia, as a pulmonary infection requiring antibiotic treatment and diagnosed by the treating physician; empyema, as a loculated fluid collection in the pleural space, seen on chest computed tomography; and wound infection, as a wound with a collection of pus that required drainage.

temporarily closed, we report herein the morbidity and mortality in a series of patients in whom, for a variety of reasons, abbreviated thoracotomies were performed and primary closure of their thoracotomies was delayed.

results

Eleven patients (5.6% of those undergoing a thoracotomy or 0.1% of all trauma patients) had their thoracic incisions closed in a temporary manner at the initial operation. Table 1 lists their mechanism of injury (8 penetrating and 3 blunt), Revised Trauma Score (RTS), Injury Severity Score (ISS), and procedure performed (thoracotomy alone, 5 patients; combined thoracotomy and laparotomy, 6). Mean ISS and RTS for all patients were 35 and 4.2, respectively. The mean ISS of surviving patients was similar to that of nonsurvivors (34 vs 38). The mean RTS was different for survivors than for nonsurvivors (5.3 vs 2.2).

The mean amounts of blood products administered intraoperatively were 14 U packed red blood cells (range, 2-28 U), 5 U fresh frozen plasma (range, 2-12 U), and 3 U platelets (range, 1-10 U). All patients required a fraction of inspired oxygen of 1.0 to achieve adequate oxygenation. All but 2 patients had profound metabolic acidemia with a pH of 7.22 or less and a mean base excess of -10.0 (range, -5 to -14). The mean intraoperative international normalized ratio and partial thromboplastin time were 1.42 and 57.6 seconds, respectively. Peak inspiratory pressure (PIP) in the operating room was greater than 30 cm H2O in all patients (mean, 38 cm H2O; range, 30-56 cm H2O).

Six patients were unable to be closed safely because of coagulopathy, 3 needed a planned reexploration, 2 had thoracic compartment syndrome, 1 manifested cardiac compressive shock with rib reapproximation, and 1 had airway hypertension with rib approximation (Table 1).

All 11 patients were transferred to the ICU; Table 2 summarizes their physiological data on arrival there. Their mean pH was 7.20; mean INR, 1.39; and mean temperature, 34.7°C. Seven patients survived to have a second operation. These patients had better physiological characteristics on arrival to the ICU than did the nonsurvivors (mean temperature, 35.4 vs 33.4°C; mean pH, 7.25 vs 7.12; and mean INR, 1.28 vs 1.48, respectively). The 4 nonsurvivors died within 24 hours after injury: 2 patients died secondary to uncontrollable disseminated intravascular coagulation (patients 3 and 4) and 2 died of severe brain injury (patients 6 and 11). The 7 patients who survived returned to the operating room when their coagulopathy had resolved, they were no longer hypothermic, and their ventilatory characteristics, specifically the airway pressures, had improved to the point that chest closure would not cause compromise.

Physiological characteristics before closing the chest are summarized in Table 2. Two of the 7 patients could not have their chest closed at the second operation because of respiratory decompensation with chest wall reapproximation; both had successful wound closure at their third operation. The mean number of days until definitive chest closure was 3.3 (range, 1-9 days). Mean PIP on arrival to the ICU was 43 cm H2O, with survivors having a lower mean (39 cm H2O) compared with nonsurvivors (51 cm H2O). At the time of closure, mean PIP for all patients was 32 cm H2O.

All 7 patients developed at least 1 complication attributable to their thoracic operation, including pneumonia (6 patients), empyema (5), wound infection (2), and mediastinitis (1). The patient with mediastinitis had dehiscence of an esophageal repair that probably was not attributable to the way his chest was closed. Six of the 7 patients underwent tracheostomy. The ICU stay ranged from 14 to 38 days, the length of time patients required mechanical ventilation ranged from 13 to 41 days, and 3 patients were transferred to another acute care hospital or a chronic care facility while still requiring mechanical ventilation for part of the day. All 7 patients who survived the first 24 hours after injury and returned to the operating room for closure of their thoracotomy survived and were discharged from the hospital.

Despite the complications they experienced, all patients who survived their initial physiological derangement lived to be discharged from the hospital. Patients 2, 5, and 7 have undergone rehabilitation and are now completely independent in all activities of daily living, tolerating a general diet and leading a normal life. Patient 1 is a paraplegic because of his injuries but otherwise is functionally independent and leading a normal life. Patient 9 had a cerebrovascular accident secondary to one of his wounds’ causing internal carotid artery thrombosis. The
patient walks with a cane and can handle simple speech but cannot tolerate oral nutrition secondary to aspiration. He receives nutrition via an enteral tube and continues to participate in rehabilitation. Patient 10 had a C6 spinal cord injury and is a quadriplegic. He lives at home, is as independent as one in his condition can be, and does not require a ventilator. Patient 8 was discharged to an extended care facility and was ultimately weaned of assisted ventilation. However, he did not regain any significant neurologic function and, after 2 months, developed a complication and was allowed to die per his family’s wishes.

Based on their Trauma and Injury Severity Score (TRISS), predicted survival was 41% for our patients in whom an abbreviated thoracotomy was performed; their actual survival rate was 64% (7 of 11 patients). The 24-hour ICU scores predicted a 43% mortality rate for the 7 survivors. The TRISS-predicted survival rate for all trauma patients who required urgent thoracotomy after trauma was 32%, compared with their actual survival of 41% (80 of 196 patients).

**COMMENT**

Damage-control laparotomy has become a popular strategy in the treatment of multiple-injured patients with impending metabolic exhaustion. The published experience to date describes its use in abdominal trauma when patients are hypothermic, coagulopathic, or acidoic to the point that they will not tolerate additional time in the operating room. Life-threatening injuries are addressed and the management of other injuries is temporized. Temporary abdominal closure using any of several previously published techniques is applied. This damage-control strategy allows the physician to resus-

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**Table 1. Demographic Data, Injury Severity, Operation, and Reason for Using Abbreviated Thoracotomy in 12 Patients**

<table>
<thead>
<tr>
<th>Patient No./Sex/Age, y</th>
<th>Mechanism of Injury</th>
<th>RTS</th>
<th>ISS</th>
<th>Operation</th>
<th>Reason for Abbreviated Thoracotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/M/26</td>
<td>GSW</td>
<td>4.07</td>
<td>13</td>
<td>Ligate brachiophecalic vein, repair R bronchus</td>
<td>Thoracic compartment syndrome</td>
</tr>
<tr>
<td>2/M/38</td>
<td>GSW</td>
<td>2.20</td>
<td>75</td>
<td>R and L atria repair, R middle and lower lobes repair, repair esophageal perforation</td>
<td>Thoracic compartment syndrome</td>
</tr>
<tr>
<td>3/M/25</td>
<td>SW</td>
<td>7.11</td>
<td>75</td>
<td>R upper, middle, and lower lobes pneumonorrhaphy, R nephrectomy, pack liver, pack R chest</td>
<td>Reexploration</td>
</tr>
<tr>
<td>4/M/16</td>
<td>GSW</td>
<td>0</td>
<td>18</td>
<td>R nephrectomy, repair R hemidiaphragm, pack liver, pack R chest</td>
<td>Coagulopathy</td>
</tr>
<tr>
<td>5/M/44</td>
<td>MVC</td>
<td>7.55</td>
<td>22</td>
<td>R lower lobectomy, R pulmonary artery and vein repair</td>
<td>Coagulopathy</td>
</tr>
<tr>
<td>6/F/60</td>
<td>MVC</td>
<td>1.87</td>
<td>50</td>
<td>R upper lobectomy, L subclavian vein ligation, release tamponade</td>
<td>Coagulopathy</td>
</tr>
<tr>
<td>7/F/25</td>
<td>GSW</td>
<td>4.62</td>
<td>9</td>
<td>R upper lobectomy, L subclavian vein ligation</td>
<td>Coagulopathy</td>
</tr>
<tr>
<td>8/M/57</td>
<td>Auto-ped</td>
<td>5.01</td>
<td>41</td>
<td>R and L lower lobes pneumonorrhaphy</td>
<td>Coagulopathy</td>
</tr>
<tr>
<td>9/M/27</td>
<td>GSW</td>
<td>7.84</td>
<td>35</td>
<td>R lower lobectomy, R middle and upper lobes pneumonorrhaphy</td>
<td>Coagulopathy</td>
</tr>
<tr>
<td>10/M/23</td>
<td>GSW</td>
<td>5.74</td>
<td>43</td>
<td>L ventricle repair, colon resection, diaphragm repair</td>
<td>Reexploration</td>
</tr>
<tr>
<td>11/M/18</td>
<td>SW</td>
<td>0</td>
<td>9</td>
<td>L subclavian artery repair</td>
<td>Coagulopathy</td>
</tr>
</tbody>
</table>

* RTS indicates Revised Trauma Score; ISS, Injury Severity Score; GSW, gunshot wound; R, right; L, left; MVC, motor vehicle crash; Auto-ped, auto-pedestrian crash, and SW, stab wound.

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**Table 2. Physiological Data Upon Arrival at ICU and at Time of Definitive Chest Closure in 11 Patients Who Underwent an Abbreviated Thoracotomy**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>T, °C</th>
<th>INR</th>
<th>pH</th>
<th>PaO2/FIO2</th>
<th>PIP, cm H2O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>32.8</td>
<td>1.14</td>
<td>7.23</td>
<td>96</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>37.0</td>
<td>1.40</td>
<td>7.09</td>
<td>480</td>
<td>33</td>
</tr>
<tr>
<td>3</td>
<td>32.5</td>
<td>1.55</td>
<td>6.97</td>
<td>436</td>
<td>50</td>
</tr>
<tr>
<td>4</td>
<td>32.1</td>
<td>1.72</td>
<td>7.04</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>36.0</td>
<td>1.41</td>
<td>7.37</td>
<td>224</td>
<td>30</td>
</tr>
<tr>
<td>6</td>
<td>35.7</td>
<td>1.24</td>
<td>7.23</td>
<td>353</td>
<td>43</td>
</tr>
<tr>
<td>7</td>
<td>34.6</td>
<td>1.05</td>
<td>7.23</td>
<td>104</td>
<td>35</td>
</tr>
<tr>
<td>8</td>
<td>35.2</td>
<td>1.39</td>
<td>7.24</td>
<td>237</td>
<td>40</td>
</tr>
<tr>
<td>9</td>
<td>35.0</td>
<td>1.56</td>
<td>7.26</td>
<td>49</td>
<td>40</td>
</tr>
<tr>
<td>10</td>
<td>37.4</td>
<td>0.99</td>
<td>7.30</td>
<td>77</td>
<td>40</td>
</tr>
<tr>
<td>11</td>
<td>33.1</td>
<td>1.40</td>
<td>7.26</td>
<td>541</td>
<td>30</td>
</tr>
</tbody>
</table>

* ICU indicates intensive care unit; T, temperature; INR, international normalized ratio of prothrombin time; PaO2/FIO2, ratio of arterial partial pressure of oxygen to fraction of inspired oxygen; PIP, peak inspiratory pressure; POD, postoperative day; DIC, disseminated intravascular coagulation; and CHI, closed head injury.
We believe the abbreviated thoracotomy strategy in only 2 required thoracotomy and decortication. Two other patients who were diagnosed as having empyema by computed tomography, computed tomographic scan findings. Of the 5 patients diagnosed as having empyema, we used a liberal definition. We present our experience using the damage-control strategy applied to complex thoracic trauma. In using the abbreviated thoracotomy, we followed the same principles advocated for patients with complex abdominal injury and impending metabolic exhaustion. Closing a thoracotomy incision requires some time to reapproximate the various layers. Temporary chest closure allowed us to rapidly close the thoracic cavity and get these critically ill patients to the ICU, where resuscitation is more efficient. In some patients with marked anasarca, temporary chest closure allowed us to avoid thoracic compartment syndrome with cardiac compressive shock and high peak airway pressure. Once edema resolved, airway pressures began to normalize, and the metabolic profile improved, patients were returned to the operating room for formal thoracotomy closure. Temporary closure of the chest was used in patients requiring reexploration, which in our series was planned in patients who developed bleeding secondary to coagulopathy or in those who required gauze packing to achieve hemostasis. Patients bled from the injury itself and from the surgical wounds; performing a temporary closure in this setting prevented us from damaging and weakening the tissues as a result of repeated closures.

Our patient survival rate compared favorably with those predicted by the TRISS method and the 24-hour ICU score; however, this is not sufficient evidence to definitively conclude that a strategy that uses temporary closure of the chest leads to improved survival. The actual survival rate for all trauma patients requiring urgent thoracotomy was also slightly better than that predicted by the TRISS method (41% vs 32%). Trauma patients who require urgent thoracotomy present in extremis and therefore have a low survival rate. These patients are at risk for metabolic exhaustion and abdominal compartment syndrome and therefore may benefit from a damage-control strategy.

Abbreviated thoracotomy and a subsequent operation were associated with a substantial number of complications, and all surviving patients developed at least 1. The severe and complex injuries and the poor physiological status of this small (5.6%) subgroup of trauma patients can explain this high rate of complications. Pneumonia is a common complication in severely injured patients who are immunocompromised and require prolonged intubation. Undergoing a subsequent operation increases the risk of wound infection. While the empyema rate seems excessive, we used a liberal definition. Empyema was diagnosed on the basis of chest computed tomographic scan findings. Of the 5 patients diagnosed as having empyema by computed tomography, only 2 required thoracotomy and decortication. Two others were treated with chest tube alone, whereas the final patient did not require any invasive intervention.

Although the number of patients and the nature of the study do not allow for rigorous statistical analysis, we believe the abbreviated thoracotomy strategy increased survival in this group of multiple-injured patients. Complications did occur but were similar to those experienced after routine thoracotomy. All patients who survived the initial 24 hours after injury lived to be discharged from the hospital. We therefore believe abbreviated thoracotomy is a strategy that surgeons should use in patients with signs of metabolic exhaustion. We recommend using a damage-control strategy and temporary chest closure in patients with thoracic injuries and clinical disseminated intravascular coagulation, hyperthermia, and acidemia, or in patients with severe anasarca who manifest cardiac compressive shock when the chest wall is closed.

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REFERENCES


