Abdominal Compartment Syndrome in the Open Abdomen

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Background: Multiple methods exist to manage in the intensive care unit the patient with an open abdomen. An increasingly common method is the vacuum packed technique. This method accommodates considerable expansion of intra-abdominal contents and should obviate the potential development of the abdominal compartment syndrome (ACS). Despite this, some patients with these temporary abdominal dressings will go on to develop ACS. For the purpose of this study we have defined this clinical entity as the open abdomen ACS.

Hypothesis: Patients with an open abdomen who develop ACS have a poor prognosis. Fluid requirements and resuscitative indices may predict which of these patients will develop open abdomen ACS.

Methods: A retrospective review was performed of patients with trauma who had an open abdomen treated with vacuum packed dressings at our urban level I trauma center. Over 1 year (July 1, 1999-June 30, 2000), 5 patients managed with an open abdomen developed ACS. These patients were compared with 15 consecutive patients with an open abdomen who did not develop clinical ACS during that same period. Fluid resuscitation, base deficit, pH, lactate level, systolic blood pressure, prothrombin time, temperature, peak inspiratory pressure, and PCO₂ were abstracted. The Fisher exact test was used for statistical analysis.

Results: In patients managed with an open abdomen, ACS developed between 1.5 and 12 hours (mean [SD], 7.5 [3.9] hours) after placement of the vacuum packed dressing. The base deficit, pH, peak inspiratory pressure, PCO₂ and lactate level were more abnormal and the crystalloid requirements were significantly higher in the ACS group. The systolic blood pressure, temperature, and prothrombin time did not differ between groups. Three patients with ACS developed a second episode of ACS. Mortality in the ACS group was 3 (60%) of 5 patients vs 1 (7%) of 15 patients in the control group.

Conclusions: Management of the open abdomen with the temporary abdominal closure does not prevent the development of ACS. Mortality is high when ACS occurs in this scenario. Severe physiologic derangement and high crystalloid requirements may predict which patients will develop ACS.

Arch Surg. 2002;137:1298-1300

A BDOMINAL compartment syndrome (ACS), first suggested in 1863 by Marey, is a term used to describe a constellation of physiologic sequelae of increased intra-abdominal pressure (IAP) or intra-abdominal hypertension (IAH). It is characterized by a tensely distended abdomen, elevated IAP and peak airway pressure, impaired ventilation associated with hypoxia and hypercarbia, decreased urine output, increased systemic vascular resistance, and decreased cardiac output. Although ACS may be associated with many clinical scenarios, it is often seen in the patient with trauma who has multiple injuries following aggressive fluid resuscitation. Patients with trauma who require lengthy operative procedures often develop the triad of hypothermia, acidosis, and coagulopathy. Abbreviated or (damage-control) staged laparotomy is used to allow adequate correction of these conditions with a set period of resuscitation in the surgical intensive care unit (ICU) prior to definitive repair and closure of the abdominal wall. To preserve the fascia, to provide ease of surgical reexploration, and to prevent the development of ACS in this high-risk subset of patients, many temporary abdominal closure techniques have been used. These techniques include towel clip skin closure (leaving fascial edges unapproximated), a sterile intravenous bag open and sewn to fascial edges (Bogata bag), or synthetic patch placement sutured to fascial edges. More recently the vacuum-pack technique has come into favor. This technique has proven to be efficient and allows for safe transport and even prone positioning of the patient if needed. Despite these attempts to obviate IAH by maintaining the abdomen open, we have observed that some patients with these temporary abdominal closures will go on to develop ACS. For this article we have defined this clinical entity as open abdomen ACS. The purposes of this article are to determine if any
resuscitation indices might help predict the patients at risk of developing ACS in the open abdomen and to define its associated mortality.

**METHODS**

A retrospective review of patients with an open abdomen treated with vacuum packed dressings was performed at our urban, level I trauma center. The vacuum packed dressing used has been well described in the literature and consists of a large antimicrobial incise drape (Ioban, 3M Health Care, St Paul, Minn) sheet held adherent side up as a sterile blue surgical towel is placed on top. The edges of the towel are then enfolded by the antimicrobial incise drape. This dressing is then placed subfascially with the antimicrobial incise drape side facing the peritoneal cavity to ensure that the bowel is in contact with a nonadherent surface. Two flat Jackson-Pratt drains are then laid alongside the subfascially placed antimicrobial incise drape–towel dressing and their tails brought out through separate skin stab wounds cephalad to the upper apex of the incision. A second large antimicrobial incise drape sheet is then placed adherent side down over the abdominal wall edges together. Concurrently, the drains are placed to low-pressure, continuous wall suction creating a vacuum. The drains allow controlled egress of fluid and the layered plastic dressing maintains a sterile, waterproof barrier.

Bladder pressures above 25 mm Hg defined IAH. Abdominal compartment syndrome was diagnosed using this bladder pressure threshold, as well as the other following clinical factors: tensely distended abdomen, elevated peak airway pressures, impaired ventilation associated with hypoxia and hypercarbia, decreased urine output, increased systemic vascular resistance, and decreased cardiac output. Over a 1-year period from July 1, 1999, through June 30, 2000, five patients with open abdomen and vacuum packed temporary abdominal closure who developed ACS (study group) were compared with 15 consecutive patients with open abdomen and vacuum packed temporary abdominal closure who did not develop ACS (control group). Total fluid resuscitation volume, base deficit, pH, lactate levels, systolic blood pressure, prothrombin times, temperature, peak inspiratory pressures, and PCO2 were abstracted. The Fisher exact test was used for statistical analysis when appropriate. All values are given as mean (SD).

**RESULTS**

From July 1, 1999, through June 30, 2000, one hundred thirty-six laparotomies for patients with trauma were performed at the University of Pennsylvania Hospital, Philadelphia. Twenty patients who required management with an open abdomen and vacuum packed temporary abdominal closure were identified. Five of these patients with an open abdomen and vacuum packed temporary abdominal closure who developed ACS during the same period, 15 consecutive patients with open abdomen and vacuum packed temporary abdominal closure who did not develop ACS were compared (control group). Total fluid resuscitation volume, base deficit, pH, lactate levels, systolic blood pressure, prothrombin times, temperature, peak inspiratory pressures, and PCO2 were abstracted. The Fisher exact test was used for statistical analysis when appropriate. All values are given as mean (SD).

In patients with an open abdomen, ACS occurred between 1.5 and 12 hours (mean, 7.5 [3.9] hours) after arrival in the surgical ICU. Bladder pressures were not routinely checked in the control group as it is not our clinical practice to check this factor in the absence of clinical suspicion, ie, a tensely distended abdomen. Therefore, no comparison of this value between the 2 groups was possible. All patients with an open abdomen having the diagnosis of ACS had bladder pressures higher than 25 mm Hg prior to reopening the abdomen. Base deficit, pH, and lactate levels on surgical ICU admission were significantly worse in the ACS group (Table 2). Systolic blood pressure, temperature, and prothrombin time did not differ between groups. The peak inspiratory pressure, PCO2, and intravenous fluids infused prior to abdominal decompression in the ACS group were then compared with the values in the control group during the first 12 hours of surgical ICU admission (Table 3). All were significantly worse in the ACS group.

Analysis of decompression and postdecompression of the ACS group demonstrated an improvement in peak inspiratory pressure (46 [9] cm H2O to 36 [4] cm H2O), base deficit (9.2 [3.6] mmol to 5.7 [0.7] mmol), and urine output (64 [56] mL/h to 242 [164] mL/h). None of these factors achieved statistical significance with P values of .064, .065, and .070, respectively. Postdecompression data were compiled over a 12-hour period. Peak inspiratory pressure and urine output were measured on hourly intervals following decompression. Base deficit was checked within 1 hour of decompression and frequently thereafter. Improvements in all 3 factors were noted immediately following decompression. Three patients in the ACS group developed a second episode of ACS. Mortality in the control group was 7% (1/13) vs a mortality of 60% (3/5) in the ACS group.

**COMMENT**

Abdominal compartment syndrome has a reported incidence of 6% in patients with severe abdominal and/or pelvic trauma undergoing emergency laparotomy. Abdominal compartment syndrome is defined as increased intracompartment pressure associated with decreased perfusion of the abdominal wall, bowel, and pelvic viscera. The diagnosis is made by direct measurement of abdominal pressure, but criteria based on clinical and laboratory indices might help predict the patients at risk of developing ACS in the open abdomen and to define its associated mortality.
compartment syndrome usually occurs within hours of arrival into the surgical ICU and causes severe disturbances of renal, respiratory, and cardiovascular functions and can increase intracranial pressure in patients with severe head trauma.\(^6\) Compromised splanchnic blood flow leads to bowel ischemia and significant acidosis.\(^7\) Subsequently, increased mucosal permeability and bacterial translocation seem to play a role in the development of multiple system organ failure.\(^8,9\) Attempts at reducing the incidence of IAH and ACS have led to the use of open abdomen techniques. Evolution of this concept has led to greater usage of the damage-control staged laparotomy and the avoidance of primary closure of fascia.\(^10,11\) This entails the placement of a synthetic material (ie, Bogota bag [an opened, empty, sterile intravenous fluid bag], polyglactin 910 knitted mesh [Vicryl mesh; Ethicon, Somerville, NJ], Whitman Patch [Star-surgical, Inc, Burlington, Vt, and others] to serve as coverage for exposed abdominal contents.

Over the last 5 years, the use of the vacuum packed technique for temporary abdominal dressings has gained wider acceptance.\(^12\) At our institution, it has supplanted all other closure techniques at the initial laparotomy. This dressing allows rapid and expedient temporary abdominal coverage and considerable increase in abdominal volume. Controlled egress of fluid from the abdomen is allowed, and a sterile barrier is maintained, while providing a durable dressing for possible prone position ventilation.\(^3\)

Management of the patient with open abdomen using the vacuum packed technique has been thought to prevent the occurrence of IAH by increasing the volume of the pseudoabdomen. We have demonstrated that a subset of patients with an open abdomen and temporary abdominal closures is still at risk of developing ACS. This entity may, in fact, be due to the efficiency with which the vacuum packed dressing is able to contain the abdominal volume and allow subsequent IAP increases associated with ongoing resuscitation requirements and capillary leak, third-space mobilization, and visceral edema.\(^13\) Temporary abdominal closure methods, although helpful, may not always provide the capacity to further increase the abdominal volume needed to prevent an increase in IAP, and thus, continued monitoring for ACS is required.

Physiologic factors and fluid requirements in the surgical ICU may predict which patients will develop ACS. Previous data reported and confirmed in our study warned that inordinately high volumes of crystalloid infusion, specifically more than 10 L, may be a risk factor for ACS.\(^11,16,17\) As we have also demonstrated, continued monitoring of IAP, base deficit, P\(_{CO_2}\), and lactate level may lead to earlier iden-

Management of the open abdomen with the vacuum-pack closure technique does not obviate against the development of ACS. Mortality is high when ACS occurs in this setting. Physiologic factors and crystalloid requirements in the surgical ICU may predict which patients will develop this ominous syndrome. Ongoing vigilant monitoring of IAP is mandatory in this patient population to recognize IAH and treat it expediently.

Accepted for publication June 29, 2002.

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### REFERENCES

13. Offner PJ, de Souza AL, Moore EE, et al. Avoidance of abdominal compartment syn-
15. Cheatham ML, White MW, Sagraves SG, Johnson JL, Block EF. Abdominal perfusion pressure: a superior parameter in the assessment of intra-abdominal hyper-

### Table 3. Comparison of Open Abdomen ACS Control Group and ACS Study Group Factors During the First 12 Hours of Surgical Intensive Care Unit Admission

<table>
<thead>
<tr>
<th>Variable</th>
<th>Open Abdomen ACS Control Group (n = 15)</th>
<th>ACS Study Group (n = 5)</th>
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</thead>
<tbody>
<tr>
<td>PIP, cm H(_2)O</td>
<td>32.0 (5.0)</td>
<td>46.0 (9.0)</td>
</tr>
<tr>
<td>P(_{CO_2}), mm Hg</td>
<td>34.4 (5.0)</td>
<td>47.0 (10.0)</td>
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<tr>
<td>Crystalloid level, L</td>
<td>16.1 (11.5)</td>
<td>27.0 (7.5)</td>
</tr>
</tbody>
</table>

*Data are given as mean (SD). ACS indicates abdominal compartment syndrome; PIP, peak inspiratory pressure. For all 3 variables P = .001.