Open abdomen with negative pressure device vs primary abdominal closure for the management of surgical abdominal sepsis: a retrospective review


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KEYWORDS: Abdominal sepsis; Open abdomen; Vacuum assisted closure; On-demand laparotomy; APACHE-1V

Abstract

BACKGROUND: Open abdomen with temporary abdominal closure remains a controversial management strategy for surgical abdominal sepsis compared with primary abdominal closure (PAC) and on-demand laparotomy. The primary objective was to compare mortality between PAC and open abdomen with vacuum assisted closure (VAC).

METHODS: Retrospective review of a tertiary center intensive care unit database (2006 to 2010) including suspected/diagnosed severe abdominal sepsis/septic shock requiring source control laparotomy. Groups were categorized according to closure method at index source control laparotomy. APACHE-IV was used as a measure of disease severity.

RESULTS: Of 211 patients, 75 PAC and 136 VAC cases were included. Controlling for disease severity, adjusted odds ratio of mortality for VAC was .41 95% confidence interval (.21, .81; P = .01) compared with PAC. PAC and VAC APACHE-IV predicted mortality rate were both 45%. VAC mortality was lower than PAC (22.8% vs 38.6%; P = .012).

CONCLUSIONS: Open abdomen with VAC is associated with significantly improved survival compared with PAC in abdominal sepsis requiring laparotomy.

Sepsis accounts for approximately 20% of intensive care unit (ICU) admissions and is the primary cause of death noncardiac ICUs, with mortality rates ranging from 25% to 50%.1–3 Large sepsis trials tend to include medical and surgical disease4 across multiple anatomic sites,5 despite evidence that site-specific research may lend more detailed insight.6 There is a lack of data describing optimal surgical techniques for the management of catastrophic abdominal sepsis.7 Many studies are limited by significant population heterogeneity, and a previous meta-analysis of surgical abdominal sepsis did not identify a significant difference in outcome between planned and on-demand approaches.8

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Traditional teaching in emergency general surgery emphasizes a single-stage operation with primary abdominal closure and on-demand laparotomy for clinical deterioration. Practice of damage control surgery was initially introduced in trauma and has transitioned to abdominal sepsis with the main objective of optimizing patient outcomes with deranged physiology. Principles of efficient control of contamination and delay of definitive procedure and fascial closure for the management of abdominal sepsis have become prevalent yet remain controversial.

Despite few prospective randomized studies, there is increasing recognition that the damage control approach can be employed to address the physiologic derangements observed in septic shock, especially in situations where source control (SC) cannot be satisfactorily obtained at the index operation.

In the 1990s, Wittmann explored the role of index SC procedure with a temporary bridging fascial closure technique followed by reassessment of the peritoneal cavity 48 to 72 hours later for abdominal sepsis. On reassessment, decisions were made regarding the need for additional lavage, debridement, and/or definitive closure. Wittmann identified that open abdomen and a staged approach was associated with improved survival compared with primary closure and relaparotomy on-demand (28.1% vs 44.2% respectively), with mortality rates below those predicted by the APACHE-II score.

The aims of this study were to primarily compare in-hospital mortality rates in abdominal sepsis patients who undergo open abdomen with temporary negative pressure dressing closure, vacuum assisted closure (VAC), vs single-stage operation with primary fascial closure (PAC). Secondly, quantify the impact of VAC on mortality while adjusting for disease severity as measured by the APACHE-IV score.

We hypothesized that use of open abdomen with temporary negative pressure dressing was associated with better survival compared with single-stage definitive procedure.

Methods

Ethics approval was obtained from the University of British Columbia Research Ethics Board.

Study design

Retrospective chart review of consecutive adult ICU admissions between the years of 2006 to 2010 at a tertiary care hospital, performed between 2011 and 2013. The ICU was a combined medical and surgical unit. Patients were identified through a prospectively collected ICU database of all admissions from January 1, 2006 to December 31, 2010 coded with the diagnosis of “open abdomen” or “abdominal sepsis”. All charts were screened using inclusion and exclusion criteria. Eligible cases were reviewed in full.

Inclusion criteria

Patients with evidence of preoperative severe sepsis or septic shock with a suspected or known abdominal source of infection requiring urgent or emergent laparotomy for SC, otherwise known as, surgical abdominal sepsis (SABS). Severe sepsis was defined as at least one clinical finding of systemic inflammatory response syndrome criteria (WBC $4 \times 10^9$/µL, T 36°C, heart rate >90 bpm, respiratory rate >20/minute) along with evidence of organ dysfunction, altered mental status, arterial hypoxemia (PaO2/FiO2 < 300), urine output less than 0.5 mL/kg/hour, creatinine increase greater than 0.5 mg/dL, ileus, platelets less than 100,000, hypoperfusion (lactate > 1 mmol/L, “mottling”), or hypotension (systolic BP < 90-mm Hg) responsive to fluid resuscitation. Septic shock was defined as hypotension nonresponsive to fluid challenge of 30-mL/kg bolus, MAP less than 60-mm Hg or use of vasopressors. All patients required admission to the ICU either secondary to SABS or developed new onset SABS while in the ICU.

Exclusion criteria

Patients less than 18 years of age, laparoscopy without conversion to laparotomy for SABS, sepsis secondary to trauma, laparotomies for nonseptic indications, and abdominal sepsis managed without laparotomy were excluded. Cases in which the attending surgeon described the degree of abdominal insult observed at the primary SC procedure as nonsurvivable (eg, global visceral ischemia) were excluded, as there would be no differential impact of management technique on survival.

Measures of disease severity

Disease severity was measured using the APACHE-IV score and predicted mortality rate (PMR). This system is a widely used tool for stratifying disease severity and predicting patient mortality in the ICU. The APACHE-IV PMR integrates the patient’s age, diagnosis, physiologic parameters, and laboratory data within the first 24 hours of ICU admission. The PMR was calculated for each patient according to the Cerner protocol.

Surgical management definitions

Patients with SABS requiring laparotomy were categorized into 2 groups based on the approach selected at the initial SC laparotomy.

- PAC—after SC procedure (debridement or resection of infected/necrotic tissue, lavage), fascia is reapproximated primarily using sutures. Decision for any subsequent reoperation was based on clinical deterioration or lack of clinical improvement with a likely
intra-abdominal cause. Intercurrent infectious foci were ruled out using laboratory tests, imaging modalities or both by the attending surgical, and/or ICU team. The decision to perform on-demand relaparotomy was made by the attending surgical team.

- VAC—after SC procedure, fascia is left open with negative pressure dressing. The decision for VAC application during the initial operation was made at the surgeon’s discretion. Common indications for VAC were: hemodynamic instability, bowel edema, gross peritoneal contamination, anticipated abdominal compartment syndrome, ongoing volume resuscitation, and/or abdominal loss of domain. Patients with VAC returned to the operating room for reassessment of the peritoneal cavity within 48 to 72 hours of index operation unless patient instability mandated earlier access. This process was repeated and terminated until the abdomen was suitable for definitive closure after macroscopic resolution of peritonitis and clinical assessment by the attending surgeon.

Statistical analysis

Analysis was stratified into VAC and PAC groups. Descriptive statistics were performed on demographic data, with standard deviations where appropriate. Continuous outcome data were analyzed using Student t test. Categorical variables were compared using Fischer’s chi-square test. Odds ratios for in-hospital mortality were calculated for VAC and PAC groups with 95% confidence intervals, and adjusted for APACHE-IV PMR. Exploratory analysis was performed on successful PAC and failed PAC subgroups. The alpha level that defined statistical significance was .05. All analyses were performed using SPSS for Macintosh, version 20.

Results

A total of 211 patients were included within the study with 75 PAC and 136 VAC cases. Demographic data are summarized in Table 1. Overall mean age was 62.8 years. Mean age was significantly elevated in PAC compared with VAC (66.6 vs 60.6).

Primary etiologies of abdominal sepsis are summarized in Table 2. The most common etiologies were; large bowel perforations, small bowel perforations, bowel ischemia, and anastomotic failure, accounting for 59% of the cohort. There was no significant difference between primary etiologies of abdominal sepsis between the PAC and VAC groups.

Outcomes are summarized in Table 3. VAC patients stayed an average of 5 days (significantly) longer in the ICU and 20 days longer in hospital compared with PAC. Overall in-hospital mortality was 28%. The VAC group had a mortality rate of 22.8% compared with 38.7% for PAC (P = .012), despite equal APACHE-IV PMR (45%) in both groups. Odds of mortality for PAC were equal to .63, compared with the odds of mortality of .30 for VAC. The unadjusted odds ratio of mortality for patients undergoing VAC was .47 compared after PAC.

After adjustment for the APACHE-IV PMR, the adjusted odds ratio of mortality for VAC patients was .41 95% confidence interval (.21, .81), compared with PAC. When controlling for disease severity, there was a significant survival advantage for those patients who underwent damage control surgery with VAC. The observed in-hospital mortality rate was indexed against the predicted by calculating an observed/predicted mortality ratio. This yielded ratios of .51 for VAC and .87 for PAC, indicating an actual mortality rate below that, which was predicted by the APACHE-1V.

A subset of PAC patients required relaparotomy for control of nonresolving sepsis or as a result of secondary complications after definitive surgery such as anastomotic leak, perforation, abscess, or abdominal compartment syndrome. These patients were labeled as “failed PAC”. At the time of relaparotomy, decision was made at the surgeon’s discretion whether to use open abdomen with negative pressure dressing vs primary closure. Failed PAC patients stayed (on average) 7 days longer in the ICU and 23 days longer in hospital compared with successful PAC patients (P = .004) and had comparable length of stay to patients who underwent VAC at their respective index operation.

Failed PAC patients had the highest in-hospital mortality of 58% despite a similar baseline APACHE-IV PMR of

<table>
<thead>
<tr>
<th>Table 1 Characteristics of SABS cohort and PAC subgroups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population characteristics</td>
</tr>
<tr>
<td>Age, mean ± SD (%)</td>
</tr>
<tr>
<td>Sex, female n (%) within PAC/VAC</td>
</tr>
<tr>
<td>Preoperative septic shock n (%)</td>
</tr>
<tr>
<td>Vasopressor use* n (%)</td>
</tr>
<tr>
<td>No. of surgeons (mean)</td>
</tr>
<tr>
<td>No. of laparotomies for source control (mean)</td>
</tr>
</tbody>
</table>

NS indicates nonsignificant statistical comparison.
PAC = primary abdominal closure; SD = standard deviation; VAC = vacuum assisted closure.

*Vasopressor medications administered in 12 hours preceding or after initial source control procedure.
49%. The observed/predicted mortality ratio in the failed subgroup was 1.2, whereas both VAC and successful PAC were below 1.0.

A total of 14 surgeons were involved with VAC management. VAC patients underwent an average of 5 laparotomies, with a mean of 4.5 SC procedures, indicating that VAC was more likely to be performed for abdominal sepsis that developed after an elective laparotomy for nonsepsis indications (eg, anastomotic leak). In comparison, failed PAC patients also required a mean of 4 laparotomies. Both VAC and failed PAC were more resource intensive in terms of surgeon manpower and involved typically one additional surgeon over the course of their treatment.

**Comments**

Between 2007 and 2011, our group managed 136 ICU patients who underwent damage control laparotomy with VAC for the management of surgical abdominal sepsis. This reflects significant single-institution experience, given that a recent 20-year review by Rausei et al\textsuperscript{17} identified 113 cases. Our data suggest that open abdomen with temporary negative pressure dressing closure for those with severe sepsis/septic shock results in a significant reduction in mortality, even when adjusting for severity of disease.

On-demand laparotomy after PAC is associated with decreased costs and avoids the morbidity of repeat surgery.\textsuperscript{18} However, clinical detection of patients who require relaparotomy is poor,\textsuperscript{19} increasing the risk of mortality from unrecognized sepsis, abdominal compartment syndrome, and multiorgan failure.\textsuperscript{20,21} Development of newer technology such as AbThera and VAC has increased ease of performing open abdomen technique, mitigating earlier concerns regarding complications, and achieving high rates of delayed PAC.\textsuperscript{20,22,23} Conversely, delaying the decision for open abdomen in sepsis is associated with increased mortality.\textsuperscript{24,25}

A randomized Dutch trial looked at planned vs on-demand laparotomy for secondary peritonitis and found no difference in mortality in the 2 approaches.\textsuperscript{26} Their technique differs from our study in that patients who underwent “planned

### Table 2  
Abdominal sepsis etiologies

<table>
<thead>
<tr>
<th>Etiology of SABS</th>
<th>Overall, n = 211 (%)</th>
<th>VAC, n = 136 (%)</th>
<th>PAC, n = 75 (%)</th>
<th>Failed PAC, n = 24 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large bowel perforation</td>
<td>33 (15.6)</td>
<td>17 (12.5)</td>
<td>16 (21.3)</td>
<td>3 (12.5)</td>
</tr>
<tr>
<td>Small bowel perforation</td>
<td>31 (14.7)</td>
<td>16 (11.8)</td>
<td>15 (20)</td>
<td>5 (20.8)</td>
</tr>
<tr>
<td>Ischemia/Infarct</td>
<td>31 (14.7)</td>
<td>22 (16.2)</td>
<td>9 (12)</td>
<td>4 (16.7)</td>
</tr>
<tr>
<td>Anastomotic failure</td>
<td>30 (14.2)</td>
<td>23 (16.9)</td>
<td>7 (9.3)</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td><em>Clostridium, difficile</em> Colitis</td>
<td>14 (6.6)</td>
<td>8 (5.9)</td>
<td>6 (8)</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td>Abcess</td>
<td>13 (6.2)</td>
<td>10 (7.4)</td>
<td>3 (4)</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td>SB0</td>
<td>9 (4.3)</td>
<td>4 (2.9)</td>
<td>5 (6.7)</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td>Necrotizing pancreatitis</td>
<td>9 (4.3)</td>
<td>8 (5.9)</td>
<td>1 (1.3)</td>
<td>1 (4.2)</td>
</tr>
<tr>
<td>Gastric perforation</td>
<td>7 (3.3)</td>
<td>4 (2.9)</td>
<td>3 (4)</td>
<td>0</td>
</tr>
<tr>
<td>Biliary complication</td>
<td>6 (2.8)</td>
<td>4 (2.9)</td>
<td>2 (2.7)</td>
<td>1 (4.2)</td>
</tr>
<tr>
<td>Abdominal wall infection</td>
<td>6 (2.8)</td>
<td>5 (3.7)</td>
<td>1 (1.3)</td>
<td>0</td>
</tr>
<tr>
<td>Large bowel obstruction</td>
<td>4 (1.9)</td>
<td>1 (.7)</td>
<td>3 (4)</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td>Fistula</td>
<td>3 (1.4)</td>
<td>3 (2.2)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Typhlitis</td>
<td>2 (.9)</td>
<td>2 (1.5)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>13 (6.2)</td>
<td>9 (6.6)</td>
<td>4 (5.3)</td>
<td>0</td>
</tr>
</tbody>
</table>

PAC = primary abdominal closure; SB0 = small bowel obstruction; VAC = vacuum assisted closure.

### Table 3  
Outcomes of SABS cohort and PAC subgroups

<table>
<thead>
<tr>
<th>Population characteristics</th>
<th>VAC, n = 136 (%)</th>
<th>PAC (all), n = 75 (%)</th>
<th>Successful PAC, n = 51 (%)</th>
<th>Failed PAC, n = 24 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>28-day mortality</td>
<td>23 (17)</td>
<td>17 (23)</td>
<td>NS</td>
<td>9 (18)</td>
</tr>
<tr>
<td>In-hospital mortality</td>
<td>31 (23)</td>
<td>29 (39)</td>
<td>.012</td>
<td>15 (29)</td>
</tr>
<tr>
<td>APACHE-1V score, mean ± SD</td>
<td>86 ± 23</td>
<td>90 ± 25</td>
<td>NS</td>
<td>90 ± 26</td>
</tr>
<tr>
<td>APACHE-1V PMR, mean ± SD</td>
<td>45 ± 24</td>
<td>45 ± 23</td>
<td>NS</td>
<td>43 ± 23</td>
</tr>
<tr>
<td>Observed/predicted mortality ratio</td>
<td>.51</td>
<td>.87</td>
<td>-</td>
<td>.67</td>
</tr>
<tr>
<td>Hospital LOS (mean days)</td>
<td>61.8 ± 57</td>
<td>40.8 ± 33</td>
<td>.008</td>
<td>33.2 ± 25</td>
</tr>
<tr>
<td>ICU LOS (mean days)</td>
<td>15.3 ± 16</td>
<td>10.2 ± 11</td>
<td>.006</td>
<td>7.8 ± 7.5</td>
</tr>
<tr>
<td>ICU readmissions</td>
<td>29 (21)</td>
<td>20 (27)</td>
<td>NS</td>
<td>11 (22)</td>
</tr>
</tbody>
</table>

ICU = intensive care unit; LOS = length of stay; PAC = primary abdominal closure; SD = standard deviation; VAC = vacuum assisted closure; PMR, predicted mortality rate.
relaparotomy” also underwent PAC at their initial operation with reopening of the abdomen at planned intervals. In addition, patients that required “imperative relaparotomy (eg, gauze packing, stapled ends without reanastomosis)” were excluded from the trial, whereas in our cohort these patients would have been managed with VAC. Their median APACHE-II score was 14.5 (PMR = 12%), with only 15% of the study cohort having scores greater than 20 (PMR ≥ 30%), with a nonstatistically significant difference in 12-month mortality of 29% (on demand) and 36% (planned). In our study cohort, the median APACHE-IV PMR was 45%, with an overall in-hospital mortality of 28%. This suggests that although there may be no mortality difference in a planned vs on-demand strategy in a preselected population, there remains a role for the use of open abdomen in patients with more deranged physiology and unfavorable abdominal environment for definitive procedures.

In our cohort, almost one-third of the PAC group failed their initial primary closure because of ongoing sepsis or secondary complications such as abdominal compartment syndrome that required reoperation. Patients who failed their primary closure underwent the same number of relook procedures as those who initially underwent VAC and they experienced the highest mortality rates in our series, exceeding the APACHE-IV PMR. Based on our data, we were unable to identify any predictive factors to preselect patients with high risk of failure after primary abdominal closure. Using a low threshold to use VAC and planned relaparotomy in the early shock period can allow for observation of a patient’s response to SC surgery and ICU resuscitation before deciding on definitive procedures. In cases where there are competing sources of clinical decline in the critically ill patient and imaging studies are equivocal, open abdomen techniques may allow easier and earlier detection and control of an ongoing septic process compared with re-exploration of a closed abdomen. The staged process of evaluating and managing a patient with an open abdomen is a resource-intensive process that requires greater involvement of care providers and perioperative resources including regular and reliable access to the operating room for reassessment.

The discrepancy between predicted and observed mortality based on APACHE-IV may indicate a lack of sensitivity for mortality prediction in patients whose response to surgical management has significant impact on their survivorship. This discrepancy is a finding that has been observed in other studies on predictive scoring systems in sepsis populations.4,27 Despite its limitations, the APACHE system is still the most widely used ICU scoring system to date and provides a comparison for measures of disease severity.28 Accounting for the differences in age and similar sepsis etiologies (Table 2), the VAC cohort may have had worse physiology scores compared with PAC. The APACHE-1V PMR indicates that all groups had a similar/equal severity of disease on ICU admission and that age alone does not explain the significant difference in mortality between VAC and PAC. This provides more support for the role of VAC in critically ill patients with worrisome physiology.

**Conclusion**

Adjusting for APACHE-1V PMR, open abdomen in the management of severe abdominal sepsis/septic shock is associated with a statistically significant better survival compared with primary abdominal closure. The highest concern resides with patients who failed primary closure, presenting an unacceptably high-mortality rate exceeding APACHE-IV PMR. Based on our results, employment of an open abdomen technique should be used in all ICU patients with severe sepsis and/or septic shock of abdominal source undergoing SC surgery.

**Study limitations**

This review is subject to the limitations associated with retrospective study designs. Recognizing the heterogeneity of the definition of abdominal sepsis, we used strict inclusion criteria to optimize uniformity of the patient population.

**References**

M.S. Bleszynski et al. VAC and primary closure in abdominal sepsis 931


Discussion

Discussant

Marilyn W. Butler, MD, MPhil (Portland, OR): For this study, the authors have performed a retrospective chart review of 211 patients who were admitted to their intensive care unit (ICU) over a 5-year period, who had sepsis requiring surgery for control of an abdominal source either on admission or during their ICU stay. The authors defined sepsis and septic shock using systemic inflammatory response syndrome criteria, and assessed disease severity and predicted mortality using APACHE-IV scores.

The authors then categorized surgical management of their patients into 2 groups: those undergoing primary abdominal closure and those undergoing vacuum assisted closure (VAC). They compared the 2 groups in terms of several factors, including mortality, APACHE-IV scores and predicted mortality rates (PMRs), and odds ratios comparing observed to predicted mortality ratio, hypothesizing that VAC was associated with better survival than primary abdominal closure.

Choice of closure was by surgeon preference, and those who failed primary abdominal closure and returned to the operating room (OR) for a subsequent laparotomy either underwent abdominal closure or VAC again based on surgeon choice. The authors found that this subset of failed primary abdominal closure patients had higher in-hospital mortality rates than the successful primary abdominal closure patients or the patients who underwent VAC at the 1st operation, and that this high mortality exceeded APACHE-IV PMRs.

Based on the higher in-hospital mortality rates in the primary abdominal closure group, the authors concluded that all ICU patients with sepsis or septic shock requiring laparotomy for an abdominal source should undergo VAC rather than primary abdominal closure.

I have several questions for the authors. First, are the 2 groups truly equivalent? Despite having comparable APACHE-IV scores and PMRs, was there a possibility of surgeon bias in the choice of closure, and could this have skewed the results? For example, if a patient were hemodynamically unstable at the end of an operation with bowel edema and a possibility of abdominal compartment syndrome, the authors concede that the surgeon was more likely to perform a VAC than primary abdominal closure.

Based on the degree of contamination and the source of the abdominal infection, would the surgeon be more apt to choose one closure over the other as well?

This leads to my next question. If the reason the primary abdominal closure group had a higher mortality rate was a delay in returning to the OR for further source control of the infection, would it have been better to compare VAC patients with primary abdominal closure patients with planned return to the OR within 48 to 72 hours? In other words, was the survival advantage conferred by the method of closure per se, or the fact that the VAC patients underwent re-exploration within 48 to 72 hours with further source control of the abdominal infection, whereas the primary abdominal closure patients did not have this advantage? To answer this question, could the authors comment on what the average time to reoperation was for the failed primary abdominal closure patients?

My next question concerns that the fact that the authors found differences in in-hospital mortality between PAC and
VAC, and between failed PAC and successful PAC, but no significant differences in 28-day mortality between the various groups, suggesting these patients suffered late hospital mortality, well beyond the average 8 to 15-day ICU length of stay. Could the authors comment on the causes of late mortality in the patient groups, and could they speculate as to why they did not find differences in 28-day mortality between the various groups?

My last question concerns the study design. Once a patient failed primary abdominal closure and underwent VAC at a subsequent laparotomy, should not those patients have been reclassified as VAC patients? If so, the high mortality of these failed primary abdominal closure patients might have raised the mortality rates in the VAC group, and there might not have been the survival advantage that the authors observed in the VAC group.

I applaud the authors for their study and for attempting to determine the best means of abdominal closure in this extremely ill patient population with abdominal sepsis.