A Case Study in Intra-abdominal Sepsis

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Intra-abdominal infections (IAIs) are a common problem for the general surgeon and a major source of morbidity and mortality in the intensive care unit (ICU). Some of these patients present with peritonitis and can rapidly progress to septic shock and need prompt resuscitation, antibiotics, and source control. The management of these patients can be complex, requiring skill in ICU management, operative source control, damage control techniques, and reconstruction. This article will use a detailed case study to outline the management of a patient with severe IAI from diverticulitis with these issues in mind.

A 67-year-old woman presented to the emergency department after a fall at home. She reported several days of abdominal pain and diarrhea. On physical examination she was febrile to 103.7°F. Pulse rate was 110 beats per minute, and blood pressure was 74/40 mm Hg with a mean arterial pressure (MAP) of 51 mm Hg. The woman was diaphoretic and lethargic but able to give a history. Abdominal examination revealed tenderness and a palpable fullness in the left lower quadrant. Rectal examination was normal. Laboratory evaluation showed a white blood cell count of 21,300 with 90% neutrophils, hematocrit of 38%, creatinine of 2.5 mg/dL, lactate of 6 mmol/L, hypokalemia, and hypophosphatemia.

KEYWORDS
- Intra-abdominal infections
- Management
- Diverticulitis
- Reconstruction
- Sepsis

KEY POINTS
- Intra-abdominal infections are a common problem for the general surgeon and can be a major source of morbidity and mortality in the intensive care unit if the patient presents with septic shock.
- The basic principles of care include prompt resuscitation, antibiotics, and source control.
- Principles of Damage Control Laparotomy can provide a framework for operative management of intra-abdominal infections.
The patient was determined to be in septic shock, and goal-directed, protocol-driven resuscitation was initiated in the emergency department. A right subclavian central venous catheter was placed, and the central venous pressure (CVP) was 4 mm Hg. A 1000 cc bolus of Lactated Ringers (LR) solution was given, which increased MAP to 60 mm Hg and CVP to 6 mm Hg. A right radial artery catheter was placed, and a norepinephrine continuous infusion was initiated and titrated to a goal MAP of 65 mm Hg. The woman received another 1000 cc bolus of LR, which brought the CVP up to 9 mm Hg; LR was then continued at 150 cc/h infusion. An indwelling urinary catheter was placed to monitor urine output (UOP). During the resuscitation, she became progressively lethargic and was electively intubated. A venous blood gas was obtained, and the central venous oxygen saturation (ScvO2) was 74%. Two sets of blood cultures were drawn, and the woman received intravenous metronidazole and ciprofloxacin for presumed diverticulitis. She was then transferred to the surgical ICU (SICU) for further resuscitation.

INITIAL RESUSCITATION

Septic shock is defined as severe sepsis with hypotension that is minimally responsive to fluid administration. The initial goals of management of this group of patients are resuscitation using early goal-directed therapy (EGDT), prompt antibiotic administration, and source control. The Surviving Sepsis Campaign (SSC) delineates the steps and protocols for the management of septic shock.

EGDT was shown to decrease in-hospital mortality in a study by Rivers and colleagues. Patients identified to be in either septic shock or having signs of severe sepsis were aggressively resuscitated via a protocol-driven treatment regimen for the first 6 hours after presentation to the emergency department. Goals of resuscitation were defined as CVP of 8 to 12 mm Hg, MAP greater than 65 mm Hg, UOP greater than 0.5 cc/kg/h, and ScvO2 greater than 70%. Patients progress through the protocol in a step-wise fashion (Fig. 1).

Patients in septic shock have a large fluid requirement to overcome the effects of vasodilation, ranging between 7 to 20 L within the first 72 hours. The goal CVP is 8 mm Hg (12 mm Hg in ventilated patients), and fluid boluses should be used to reach and maintain this level of preload. Two broad groups of fluids have been used for resuscitation, crystalloids and colloids. The most commonly used crystalloid solutions are LR solution and normal saline (NS) solution. Both are readily available and inexpensive. Caution should be used with large-volume administration of NS, as a hyperchloremic metabolic acidosis can occur due to a large chloride load (154 mEq/L). LR contains less chloride but also contains 4 mEq/L of potassium, which may not be well tolerated in patients with renal failure. Although both of these fluids are isotonic, a significant volume will migrate into the extravascular space due to increased capillary permeability and changes in oncotic pressure. Given the capillary leak, albumin is often used as a primary resuscitative fluid with the assumption that it will remain in the intravascular space. There are numerous single-institution series and meta analyses comparing crystalloids and albumin for resuscitation that have had mixed results.

A large randomized–controlled trial was undertaken enrolling 7000 hypotensive patients admitted to the ICU, 1200 of whom had severe sepsis. They were randomized to either NS or 4% albumin as the primary resuscitative fluid. Overall there was no difference in morbidity or mortality in either group. In the subset of patients with severe sepsis, the mortality rate was 30.7% versus 35.3%, which did not reach statistical significance. Although the conclusion of the authors was that both 4% albumin and NS were clinically equivalent treatments, many have suggested crystalloid be used due to its decreased cost.
Persistent hypoperfusion can lead to end organ damage and death in patients suffering from septic shock. A MAP of greater than 65 mm Hg has been suggested as a target to maintain perfusion based on animal studies, but there is little experimental evidence for this goal in humans. Patients with baseline comorbidities may in fact require a higher goal MAP, and standard measures of perfusion should be used to titrate the MAP to higher level. Adequate fluid resuscitation as measured by a CVP of 8 to 10 mm Hg should be achieved before the administration of vasopressors; however, patients in severe hypoperfusion states may require early administration of vasopressors. The SSC recommends either norepinephrine or dopamine be started as a first-line agent. Norepinephrine has mainly alpha-adrenergic agonist effects with some beta-adrenergic activity. Dopamine has dose-dependent effects, with moderate doses having a predominant beta-adrenergic activity and higher doses exhibiting potent alpha-adrenergic activity. However, this dose-dependent response is unreliable in critically ill patients. Until recently, there had been no large-scale trial

**VASOPRESSORS**


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comparing the choice of vasopressors in septic shock. A large observational trial evaluated over 1000 patients in shock, with 462 in septic shock.\(^{11}\) Although most patients received multiple vasopressors, dopamine use was an independent predictor of mortality in multivariate analysis (odds ratio [OR] 2.05 (1.25–3.37)). The sepsis occurrence in acutely ill patients II (SOAP II) trial group study\(^{12}\) prospectively studied 1679 patients, 1044 of whom were in septic shock. They were randomized to either norepinephrine or dopamine as the first-line agent with open-label use of other vasopressors as needed. There was no difference in mortality or secondary end points except for a higher incidence of arrhythmias (24% vs 12%) in the dopamine group. A recent meta-analysis of 4 observational and 6 randomized trials showed an increased odds ratio of mortality and arrhythmias associated with use of dopamine.\(^{13}\) The authors suggest the use of norepinephrine due to the decreased rate of adverse events.

Vasopressin acts as both a vasopressor, via the V1 receptor on vascular smooth muscle, and as an antidiuretic hormone via V2 receptors on the renal collecting duct system.\(^{14}\) After an initial surge in vasopressin levels, there is a relative vasopressin deficiency in patients in septic shock. Infusion of vasopressin at physiologic levels (0.01–0.04 U/min) reduces the amount of catecholamines needed to maintain adequate perfusion.\(^{15}\) Administering doses higher than 0.04 U/min of vasopressin is associated with potentially deleterious vasoconstriction of renal, mesenteric, pulmonary, and coronary vasculature.\(^{14}\) The vasopressin and septic shock trial (VASST) investigators\(^{16}\) compared norepinephrine infusion to norepinephrine with vasopressin titrated to 0.03 U/min in 778 patients with septic shock. All patients enrolled were on at least 5 \(\mu\)g/min of norepinephrine and were either started on vasopressin titrated to 0.03 U/min or additional norepinephrine (5–15 \(\mu\)g/min). Overall there was no difference in 28-day or 90-day mortality or in serious adverse events. However, in the predefined less severe septic shock group (>15 \(\mu\)g/min norepinephrine infusion at time of enrollment), there was a significant reduction in 28-day and 90-day mortality rates in the vasopressin group (26.5% vs 35.7% \(P = .05\)). Based on these results, the early addition of vasopressin at 0.04 U/min infusion is recommended.\(^{5,17}\)

**END POINTS OF RESUSCITATION AND MONITORING**

The goal of therapy is to maintain adequate end organ perfusion and function. As there are few direct measures of perfusion, the effectiveness of fluid resuscitation and vasopressor use is measured by end points of resuscitation. Although there is controversy regarding their validity, the most commonly used end points are MAP, CVP, UOP, ScvO2, serum lactate clearance, and correction of a base deficit.\(^{18}\)

Although varying targets of MAP have not been directly studied in septic shock, levels of greater than 65 mm Hg are thought to preserve tissue perfusion.\(^{9,19}\) Patients with underlying comorbidites will likely require a higher MAP to maintain autoregulation and tissue perfusion. CVP is used as a surrogate for preload with a goal pressure of 8 to 12 mm Hg.\(^{2,3}\) However, the validity of CVP is often called into question as it is affected by numerous factors.\(^{20}\) According to the Surviving Sepsis Guidelines CVP of 8 mm Hg indicates adequate preload; however, in practice, patients with a lower CVP may actually be volume overloaded. A practical approach to a hypotensive patient with low CVP is to administer a fluid challenge and monitor change in CVP and MAP. If there is no concomitant rise in both values, further volume resuscitation may be harmful to the patient.

Given the potential unreliability of the CVP measurement, pulse pressure variation may predict those patients who are potentially fluid responsive.\(^{21}\) Briefly, a calculation
is performed using the maximal pulse pressure during inspiration and the minimal pulse pressure measured in expiration. A percentage difference of 13% is suggestive of patients who would be responsive to fluid.22 There are commercially available devices that will measure pulse pressure variation as well as determine stroke volume and cardiac output from an arterial catheter.23 A full discussion of pulse pressure variation and these devices is beyond the scope of this article.

Lactic acidemia is associated with hypoperfusion and may be a prognostic marker in patients in septic shock.18 A single lactate level is likely of low clinical utility; however, the clearance of serum lactate levels over time can predict mortality in patients with severe sepsis. Serial lactate levels are drawn, and then lactate clearance is calculated by the equation \[
\frac{\text{lactate}_{\text{initial}} - \text{lactate}_{\text{delayed}}}{\text{lactate}_{\text{initial}}} \times 100%.\]
Nguyen and colleagues24 studied lactate clearance in 111 patients initially undergoing EGDT in the emergency department. Those patients who had a lactate clearance greater than 10% over the first 6 hours had a lower in-hospital, 30-day and 60-day mortality rates. Jones and colleagues25 prospectively compared lactate clearance to monitoring ScvO2 as the method to measure total body oxygen metabolism. Two hundred forty-seven patients were randomized and underwent EDGT as outlined by Rivers and colleagues3 (Table 1), except lactate clearance of greater than 10% was used instead of ScvO2 of greater than 70% as the goal in the last step of the protocol in 1 group. There was no difference in mortality in the 2 groups, and they concluded a protocol targeting lactate clearance was not inferior to a protocol that used ScvO2.

### EMPIRIC ANTIBIOTICS

Prompt administration of empiric intravenous antibiotics likely to cover pathogens causing sepsis is recommended by the SSC.2 It is suggested that an important portion of a sepsis bundle is the rapid administration of antibiotics.26 In a retrospective study of over 2000 patients in septic shock, Kumar and colleagues27 noted a decrease in survival by 7.6% for each hour of delay in administering antibiotics. Patients who received antibiotics within the first 30 minutes of hypotension had a survival of 82.7% versus 42% if treatment was delayed to 6 hours. Gaieski and colleagues28 prospectively studied 261 patients undergoing EGDT and reported a lower mortality when antibiotics were given within 1 hour of arrival to the emergency department (19.5% vs 33.2%).

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<tr>
<th>Table 1</th>
<th>Antimicrobial choices for acute diverticulitis</th>
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<tr>
<td><strong>Monotherapy</strong></td>
<td><strong>Combination</strong></td>
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<tr>
<td>Low Risk</td>
<td>Ampicillin/sulbactam</td>
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<td>Ticarcillin/clavulanate</td>
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<td>Moxifloxacin</td>
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<td>High Risk</td>
<td>Imipenem/cilastatin</td>
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<td>Meropenum</td>
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<td>Piperacillin/tazobactam</td>
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See text for definition of low- and high-risk patients.

a Ciprofloxacin, levofloxacin, or gatifloxacin.

b Gentamicin or tobramycin.

c Cefepime, cefotaxime, ceftazidime, ceftizoxime, or ceftriaxone.

Patients with IAIIs should be administered empiric antibiotics that cover enteric gram-negative aerobic and facultative bacilli and enteric gram-positive streptococci. The most commonly isolated organisms in diverticulitis mirror those in other IAIIs. A majority of patients will have mixed aerobic and anaerobic bacteria, with *Escherichia coli* and *Bacteroides fragilis* as the most common isolates, and antimicrobial therapy should be directed toward those organisms. Although there are not recommendations for specific antibiotic regimens, guidelines for IAIIs were recently updated. There is little level 1 evidence on antibiotic selection, and most often recommendations are made based on expert consensus. However, stratifying patients as low risk or high risk can help the clinician navigate guidelines. Low-risk patients generally present with a community acquired infection and have few preexisting comorbid conditions. Conversely, high-risk patients present with malnutrition, liver or kidney dysfunction, higher Acute Physiology and Chronic Health Evaluation (APACHE) II scores, and hospital-acquired infections. Specific regimens for treatment of complicated diverticulitis can either be single-agent or combination therapy, with regimens recommended for both low-risk and high-risk patients (Table 1). Community-specific factors such as the presence of multidrug-resistant organisms (*Pseudomonas*, extended-spectrum β-lactamase producing *Enterobacteriaceae*, and methicillin-resistant *Staphylococcus aureus*) will affect choice of antibiotic. Antifungal therapy is not recommended in low-risk patients unless *Candida* is grown from intra-abdominal cultures. Antifungal use in high-risk patients should be considered on a case-by-case basis. Fluconazole is the antifungal of choice; however, in patients with resistance or in those critically ill, therapy with an echinocandin (caspofungin, micafungin, or anidulafungin) is acceptable.

The optimal duration of antimicrobial therapy is an unanswered question. The Surgical Infection Society (SIS)/Infectious Diseases Society of America (IDSA) guidelines recommend limiting therapy to 4 to 7 days unless there is inadequate source control. Patients undergoing therapy for greater than 7 days are at risk for toxicities and superinfection with *Clostridium difficile*, with no decrease in treatment failures. Patients who have adequate source control will show signs of resolution of infection (afebrile, normal white blood cell counts, resumption of an oral diet) within the 7 days of antimicrobial treatment.

### Source Control

Source control is a cornerstone in the management of the patient with septic shock. The core elements of source control include rapid diagnosis and control of the infection via drainage of an abscess, debridement of devitalized or infected tissue, or removal of an infected medical device. The SSC guidelines recommend all patients with severe sepsis be “evaluated for the presence of a focus of infection amenable to source control measures.” Indwelling urinary catheters or vascular catheters are obvious examples of infected medical devices that can be removed or replaced with minimal morbidity. Orthopedic hardware, prosthetic mesh and prosthetic heart valves need to be evaluated on a case-by-case basis.

Source control is an integral component of the management of patients with IAIIs. The most common etiologies of IAI include pancreatic necrosis, biliary tract or gastrointestinal perforation, or inflammation. Failure to achieve source control in patients with IAI is associated with increased postoperative infections and morbidity. Although there are no randomized trials regarding the optimal management of IAI, current recommendations suggest using the method that causes the least physiologic upset possible, minimizing anatomic and physiologic trauma. Image-guided percutaneous drainage is often the mode of choice in patients with well-localized and
contained intra-abdominal abscess or in those who are poor surgical candidates. However, in the case of ongoing contamination from gastrointestinal ischemia or perforation, open surgical drainage and debridement are necessary for appropriate source control. In these cases, wide drainage of purulence, resection of necrotic or ischemic bowel, and debridement of fecal matter, hematoma, and necrotic tissue are required.36

**ADJUNCTIVE MEASURES**

The recommendations regarding the use of corticosteroids have changed over time based on 2 major studies in patients with septic shock. Annane and colleagues37 demonstrated a decreased need for vasopressors in patients with refractory septic shock and a survival advantage in those with relative adrenal insufficiency. The corticosteroid therapy of septic shock (CORTICUS)38 trial studied patients with less severe septic shock and noted a decreased duration of shock in those treated with corticosteroids but no mortality difference. They did not assess patients for relative adrenal insufficiency. The SCC guidelines recommend corticosteroids be used in patients with refractory septic shock (poorly responsive to fluids and vasopressor therapy) and do not recommend routine assessment for relative adrenal insufficiency.

Recombinant human activated protein C (rhAPC), also known as drotrecogin alfa, was included in the SSC guidelines based on the prospective recombinant human activated protein C worldwide evaluation in severe sepsis (PROWESS) study group39 and administration of drotrecogin alfa (Activated) in early stage severe sepsis (ADDRESS) study group40 studies. The PROWESS trial examined patients with severe sepsis and an average APACHE II score of 25 and demonstrated a lower risk of 28-day mortality in those treated with rhAPC (24.7% vs 30.8%). Based on the results of a subsequent subgroup analysis,41 the ADDRESS trial enrolled patients with an APACHE II score less than 25 and showed no difference in mortality. The final SSC recommendation was that administering rhAPC to patients with sepsis-induced multiple organ dysfunction and a high risk of death or an APACHE II score greater than 25. The prospective recombinant human activated protein C worldwide evaluation in severe sepsis and septic shock (PROWESS-SHOCK) study42 enrolled adults with severe sepsis and high risk of death in an attempt to provide further validation of the previous studies. The study has been completed, but the results have not been published as of yet. However, preliminary results showed a 28-day all-cause mortality rate of 26.4% in patients treated with rhAPC compared with 24.4% in those given placebo. Based on these preliminary data, the US Food and Drug Administration (FDA) withdrew drotrecogin alfa from the market.43 At this time, rhAPC should not be used in any patients with septic shock.

**Diagnosis and Nonoperative Management of Diverticulitis**

While in the SICU, the patient’s resuscitation continued; the CVP was maintained between 8 and 10 mm Hg with LR administration, and her norepinephrine requirements diminished. The patient’s UOP improved to 0.6 cc/kg/h. Serial lactate levels were drawn and were down trending throughout the initial 12 hours. The following morning, her serum creatinine improved to 1.3 mg/dL, and she underwent a noncontrast computed tomography (CT) scan of the abdomen and pelvis. There was extensive diverticulosis in the sigmoid and descending colon as well as thickening of the wall of the sigmoid colon. There was also a 7 × 10 cm fluid collection in the left paracolic gutter with surrounding inflammation. This was felt to be consistent with a Hinchey stage 3/4 perforation. The following morning, she returned to the radiology department for a percutaneous drainage of the abscess. The cavity was accessed, and feculent
The diagnosis of acute diverticulitis can often be made based on history and physical findings, especially in patients who have had previously confirmed diverticulitis. However, in many cases of abdominal pain, it may be uncertain whether acute diverticulitis is present, and adjunctive studies are helpful and warranted. Alternative diagnoses include irritable bowel syndrome, gastroenteritis, bowel obstruction, inflammatory bowel disease, appendicitis, ischemic colitis, colorectal cancer, urinary tract infection, kidney stones, and gynecologic disorders. An elevated white blood cell count often is helpful in confirming the presence of an inflammatory process.

Although several different modalities have been used to evaluate patients with suspected diverticular disease, CT has emerged as the study of choice. Advantages of CT scanning include the ability to make an accurate diagnosis and stage the severity of disease, and the therapeutic ability to drain an abscess with CT guidance. Disadvantages of CT scan include radiation exposure and the cost of the examinations.

CT findings consistent with diverticulitis were first described more than 25 years ago. These signs included the presence of diverticula, pericolic fat stranding, colonic wall thickening more than 4 mm, and abscess formation. CT has the added advantage of detecting other intraperitoneal findings, including hepatic abscesses, pyelophebitis, small bowel obstruction, colonic strictures/obstruction, and colovesical fistulas. A prospective study found a sensitivity of 97%, specificity of 98%, and global accuracy of 98%. It identified localized perforation and abscesses with a sensitivity of 100% and specificity of 91%.

Multiple classification systems for diverticulitis exist. Prior to the routine use of CT scan, Hinchey and colleagues published their classification for acute diverticulitis. The Hinchey classification is used in international literature to distinguish 4 stages of perforated disease identified at the time of surgery. There are many modifications to the Hinchey classification that incorporate CT scan findings. One such modification was made by Kaiser and colleagues (stage 0 mild clinical diverticulitis, stage 1a confined pericolic inflammation, stage 1b confined pericolic abscess, stage 2 pelvic or distant intraabdominal abscess, stage 3 generalized purulent peritonitis, stage 4 fecal peritonitis), which was based on clinical, CT, or operative findings. Other classifications are based solely on CT scan with the argument that CT findings are the most valuable indication as to the likelihood that medical treatment with antibiotics will fail. Ambrosetti and colleagues have proposed such a classification of sigmoid diverticulitis. Diverticulitis is subdivided into moderate disease or mild disease in the case of localized sigmoid wall thickening (>5 mm) and inflammation of the pericolic fat. The term severe disease is used instead in the case of abscess, extraluminal air or extraluminal contrast extravasation. Irrespective of the classification system used CT scan findings are an important aspect of developing a treatment plan.

Acute diverticulitis can be divided into complicated and uncomplicated diverticulitis. Complicated diverticulitis refers to acute diverticulitis accompanied by abscess, fistula, obstruction, or free intra-abdominal perforation. Most patients with uncomplicated sigmoid diverticulitis respond to medical treatment with broad-spectrum antibiotics. Hospital admission is dependent on systemic illness, age, and comorbidities. Even when hospital admission is necessary, an initial conservative approach has been validated. Patients with uncomplicated diverticulitis generally experience significant decreases in their abdominal pain, temperature and white blood cell count within the first 48 hours after initiation of antibiotic therapy.
Diverticular abscesses are a common complication of acute diverticulitis, occurring in 15% to 20% of cases. According to the American Society of Colon and Rectal Surgeons practice parameters for sigmoid diverticulitis, “Radiologically guided percutaneous drainage is usually the most appropriate treatment for patients with a large diverticular abscess.” Recommendations also include hospitalization, intravenous antibiotics, and medical treatment alone for abscesses less than 2 cm. Other studies have advocated the routine percutaneous drainage of abscess larger then 3 to 5 cm or all pelvic abscesses.

Operative Management of Diverticulitis

The next day, the patient was taken to the operating room for failure of nonoperative management. She underwent a sigmoid colectomy with Hartmann pouch. Prior to creation of the end colostomy and abdominal closure, she became hypothermic, hypotensive, and acidic. The procedure was terminated, and the woman’s abdomen was temporarily closed with an abdominal vacuum pack.

Emergency surgery is indicated in patients with diffuse peritonitis or for those who fail nonoperative management of acute diverticulitis. This is usually seen in the setting of Hinchey 3 or 4 diverticulitis. The standard of care in most cases is a sigmoid resection, closure of the rectal stump, and creation of an end-descending colostomy, also known as a Hartmann procedure. Widespread use of the Hartmann procedure has replaced delayed sigmoid resection, known as the 3-staged technique, which was commonly practiced before the 1980s, and involved proximal diversion, subsequent resection and primary anastomosis with maintenance of stoma, and finally colostomy closure. The aggregate mortality in a total of 1051 patients reported in 54 combined studies between 1966 and 2003 was almost 19% and was associated with a 24% incidence of wound infection and a 10% incidence of stoma complications. Unfortunately, bowel reconstruction after Hartmann procedure requires a new laparotomy, and a high percentage of patients will not undergo further surgery due to other medical problems, and therefore remain with a permanent stoma.

A single-staged technique of sigmoid resection with primary anastomosis is becoming a recognized alternative to Hartmann procedure for the treatment of acute diverticulitis. Primary resection and anastomosis have gained popularity after their successful application in the repair of penetrating traumatic colon injuries. A subsequent case series using primary resection and anastomosis with or without protective stoma and intraoperative lavage has been reported in the treatment of acute diverticulitis, and several advantages of this approach have been recognized. Creation of an anastomosis during the initial resection avoids the technical difficulty of colostomy reversal and the additional cost and length of hospital stay, and improves the likelihood for maintaining intestinal continuity. This approach is an acceptable alternative to treating patients with low-grade Hinchey 1 and 2 disease who undergo laparotomy for diverticular peritonitis, and it is supported by the European Association of Endoscopic Surgeons as a treatment option in perforation with purulent peritonitis (Hinchey 3) when used with protective stoma. Recent comparative reviews of the literature reflect favorably on the use of primary resection and anastomosis compared with Hartmann procedure in advanced-staged diverticulitis, but they must be interpreted with caution due to considerable selection bias, lack of prospective randomized trials, and heterogeneity of patient disease. Primary anastomosis is contraindicated in fecal peritonitis, septic shock, hemodynamic instability, chronic steroid therapy, and poor condition of the patient.
Laparoscopic peritoneal lavage is an alternative in the management of Hinchey grade 2 pelvic abscesses and perforated diverticulitis with diffuse purulent peritonitis. There are case series published and prospective studies showing benefits compared with conventional management. Proponents suggest it achieves a lower mortality rate and stoma formation rate, less wound infections, and shorter operating time. No significant differences were found with respect to recurrence rates compared with resection and primary anastomosis. But even though there is some available evidence, the lack of prospective clinical trials, with the exception of the study published by Myers and colleagues, has limited the widespread use of laparoscopic lavage.

**Damage Control for Intra-Abdominal Sepsis**

The patient was brought back to the SICU and underwent continued resuscitation. A lithium indicator dilution cardiac output monitor device (LiDCO) was used to determine she had fluid-responsive hypotension. At this point her hematocrit had fallen to 25, and international normalized ratio (INR) was 1.4; she was transfused 2 units pRBC and 2 units fresh frozen plasma (FFP). Over the next 12 hours, her vasopressor requirements were eliminated, and her acidosis improved. On postoperative day (POD) 2, she was taken back to the operating room for a planned relaparotomy. Her abdomen was washed out, and there were no signs of ongoing contamination or peritonitis. Her small bowel was edematous, and the fascia was unable to be approximated without tension. A postpyloric soft feeding tube was placed intraoperatively, and the temporary abdominal vacuum pack (VP) was reapplied before she was returned to the SICU. At this point, her hemodynamics had normalized; her UOP improved to 1 cc/kg/h, and lactate was 1 mmol/L and no longer acidic. Over the next 48 hours, the patient was diuresed with furosemide to target 1.5 L net fluid negative per day, and enteral feeds were started at 10 cc/h. On POD 4, she underwent washout of her abdomen, sigmoid colostomy, and primary closure of her fascia and skin. She was then extubated and transferred to the surgical ward and had an uneventful recovery. Nine weeks later, she underwent colostomy takedown without incident.

**DAMAGE CONTROL LAPAROTOMY**

Damage control laparotomy (DCL) refers to a sequence of an abbreviated initial laparotomy with the initial goals of controlling hemorrhage and contamination, a period of resuscitation, subsequent operations, and a definitive abdominal wall closure. DCL was formalized 20 years ago by Rotondo and colleagues as a method of reducing the morbidity and mortality associated with severe intra-abdominal injury. Over the past 15 years, there has been widespread adoption of DCL techniques, and the open abdomen has become commonplace in surgical ICUs. The open abdomen technique has long been used to treat severe intra-abdominal infections. Indications for DCL in severe IAI are similar to those in severe abdominal trauma: temperature less than 35°C, pH less than 7.20, a base deficit greater than 8, and laboratory or clinical evidence of coagulopathy. Additionally, indications include massive volume resuscitation, ongoing contamination, inadequate source control, hemodynamic instability, need for second-look procedure, primary prevention of abdominal compartment syndrome (ACS), and development of multisystem organ failure.

The sequence of damage control laparotomy as described for trauma is adapted to IAI with several modifications. The initial resuscitation and evaluation period, termed ground zero, is generally longer, requiring several hours to restore adequate perfusion in the septic patient. The goals of this period are to replace circulating volume with...
crystalloids and to begin correcting the acidosis and coagulopathy associated with sepsis.

Once the patient has undergone a period of resuscitation, an exploratory laparotomy for source control is undertaken. The goals of this initial operation are to drain any intra-abdominal abscess and resect ischemic or necrotic tissue before the patient succumbs to physiologic fatigue. Most often this involves resecting a portion of hollow viscus and leaving the bowel in discontinuity.

After source control is obtained, the method of temporary abdominal closure (TAC) needs to be considered. The principles of TAC are containing the intra-abdominal contents, protection of the bowel, preservation of the fascia, and control of the peritoneal effluent. Numerous strategies for TAC have been described, ranging from skin-only closures with towel clips or running monofilament, absorbable or nonabsorbable mesh closure, VP, and vacuum-assisted wound management. Primary skin closure and mesh placement have largely been replaced by vacuum dressings. They offer the advantage of easy placement and removal to facilitate multiple subsequent procedures, control and quantification of the peritoneal effluent, and preservation of the fascia. The VP, as described by Barker and colleagues, has become the most widely used method of TAC and is the current standard of care. Most commonly, the VP is constructed in 3 layers. A sterile polyvinyl sheet (1010 large bowel bag, 3M Health Care, St. Paul, Minnesota) is placed directly above the abdominal viscera and below the anterior abdominal wall. Either a moist towel or gauze is placed in the subfascial space, and 2 large silicone drains or nasogastric tubes are brought out through the superior portion of the wound. Finally, large adhesive drape (Ioban, 3M Health Care) is used to cover the entire defect, and the drains are connected to suction via a Y connector to provide continuous negative pressure.

A commercially available vacuum assisted closure device is available for TAC (VAC Abdominal Dressing System and AbThera, KCI San Antonio, Texas). It is constructed similar to the VP. A nonadherent plastic drape is placed below the abdominal wall; however, the towel is replaced by a porous polyurethane sponge. An adhesive drape and drain complete the dressing. Excellent rates of fascial reapproximation and low rates of enterocutanous fistula have been reported with vacuum-assisted closure devices. At this point, no prospective comparison of VP dressings and vacuum-assisted closure devices has been undertaken.

After TAC has been performed, the patient returns to the ICU for a continued period of resuscitation. It is not uncommon for the patient to need aggressive resuscitation for 24 to 48 hours after the initial laparotomy for source control. The patient should be resuscitated based on the principles previously described. Within 24 to 48 hours, the patient should be taken back to the operating room for re-exploration and evaluation for closure. The TAC is removed, and the abdomen is re-explored, taking care to examine the site of the source of the intra-abdominal sepsis. Frequently, further debridement of necrotic tissue or drainage of accumulated purulent fluid is necessary. Extensive intra-abdominal lavage with sterile saline is undertaken to decrease the bacterial burden and remove any nonadherent hematoma or fibrous material. Existing staple lines and anastomoses should be gently examined for their integrity. Restoration of gastrointestinal continuity is delayed until the degree of peritonitis has decreased. In some patients with intra-abdominal sepsis, creation of an end stoma may be preferable over primary anastomosis. Alternatively, a diverting loop ileostomy protecting a distal colonic primary anastomosis is a safe strategy. If a prolonged period of an open abdomen is anticipated, stomas should be placed as far lateral as possible on the abdominal wall to provide maximal abdominal wall mobility during closure. This can be done at the initial relaparotomy or delayed to a subsequent procedure.
At this point, an evaluation for closure is undertaken. If bowel edema has resolved, and the fascia can be brought together without undue tension, then primary closure should be attempted. Communication with the anesthesia team at this point is important; if the peak inspiratory pressures increase by more than 10 mm Hg during closure, then fascial closure should be abandoned. A rise in peak pressure can place the patient at risk for dehiscence or abdominal compartment syndrome. Most patients undergoing DCL for IAI will have a significant amount of bowel and mesenteric edema precluding early closure. At this point, the TAC should be reapplied and patient returned to the ICU.

It may take up to 7 to 10 days, during which the patient undergoes relaparotomy every 48 to 72 hours for the visceral edema and inflammatory response to subside enough to allow closure. However, during this time period, the fascia retracts laterally and becomes fused to the overlying fat; this makes primary closure impossible. Several methods may prevent the retraction of the myofascial unit, namely removable prostheses, dynamic retention sutures, and the VAC dressings. Wittman developed a burr-like device consisting of 2 sheets of a Velcro-like material sutured to the fascia. As in the VP, a plastic drape is placed under the abdominal wall, and the Wittman Patch (Starsurgical, Burlington, Wisconsin) is sewn in and the sheets compressed together and adhered. A dressing similar to the VP is placed above the patch to control the peritoneal effluent. At subsequent relaparotomies, the sheets are easily separated and trimmed and then reapproximated until the fascia can be closed. Several groups have reported success using this technique with closure rates of 75% to 100%. Dynamic retention sutures can be used to maintain the myofascial unit and can be tightened at the bedside in the ICU. The VAC dressing as described previously can provide excellent fascial reapproximation with success rates ranging from 65% to 100% in trauma patients. Unfortunately, closure rates after sepsis are much lower overall. This lower rate persists with the VAC dressing, as Wondberg reported a fascial closure rate of 33% in patients with IAI.

If the abdominal fascia is not closed within 10 to 14 days using the previously described techniques, it is recognized that the fascia will not come together because of massive visceral edema, loss of domain, and the presence of a fixed visceral block. The open abdomen is then allowed to granulate in, and a split-thickness skin graft (STSG) is used to cover the wound. Over the ensuring 6 to 12 months, the inflammatory response resolves, and the granulation tissue dissipates: at this time the skin can be elevated from the underlying viscera. The STSG is removed, and the fascial defect is closed, either with a primary closure, biologic mesh, or a component separation.

REFERENCES


88. Wittmann DH, Aprahamian C, Bergstein JM. Etappen lavage: advanced diffuse peritonitis managed by planned multiple laparotomies utilizing zippers, slide


