Open Abdomen: The Surgeons' Challenge

Juan José Santivañez Palomino, Arturo Vergara and
Manuel Cadena

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Abstract

An open abdomen is defined as purposely foregoing fascial closure of the abdomen after the cavity is opened. Management of complex abdominal problems with the open abdomen and temporary abdominal closure techniques has become a common and valuable tool in surgery. Several challenging clinical situations can necessitate leaving the abdominal cavity open after surgery, resulting in an open abdomen. The indications for open abdomen are as follows: Damage control for life-threatening intraabdominal bleeding, severe acute pancreatitis, severe abdominal sepsis, and prevention and treatment of the abdominal compartment syndrome. Damage control surgery is based on a rapid control of bleeding and focuses on reversing physiologic exhaustion in a critically ill or injured patient. In severe abdominal sepsis, the intervention should be abbreviated due to suboptimal local conditions for healing and global susceptibility to spiraling organ failure. Abdominal compartment syndrome (ACS) is commonly encountered and the only solution is decreasing the pressure by decompressive laparotomy. Open abdomen is associated with significant complications, including wound infection, fluid and protein loss, a catabolic state, loss of abdominal wall domain, and development of enteroatmospheric fistula; however, if the indications are clear, it can become a most valuable resource in treating these conditions.

Keywords: open abdomen, laparostoma, damage control, abdominal compartment syndrome, abdominal sepsis

1. General aspects

The open abdomen is the most challenging of the wounds that a surgeon faces, that is because of the metabolic, physiological, and dynamic implications that this condition entails. An open abdomen is defined as a purposely foregoing fascial closure of the abdomen after the cavity has been opened [1, 2]. Throughout the years, management of complex abdominal problems dealing with an open abdomen and techniques that handle the temporary closure of the abdominal wall have become common and valuable tools for the surgeon [3]. Several challenging clinical situations force the surgeon in leaving the abdominal cavity open after surgery, resulting in an open abdomen or laparostoma [4].

There are several indications for open abdomen, some of which are severe acute pancreatitis [5], damage control for life-threatening intra-abdominal bleeding (with a need for a "second look"), severe abdominal sepsis, and finally, prevention and treatment of an abdominal compartment syndrome [3]. In our recent experience, we have found that peritoneal failure, as the result of the imbalance between the mechanisms of defense of the guest and the peritoneal injury, is the clear indication of the need for the open abdomen.

2. Damage control

Damage control surgery is based on a rapid control of bleeding and focuses on reversing physiologic exhaustion in a critically ill or injured patient [6]. Initially, it was introduced in the field as a temporizing measure used to salvage trauma patients very near death. Through time, damage control surgery has evolved to become the *preferred method for those general surgical patients whose physiological derangements do not allow the completion of an intended operation* [7].

About 10–15% of all laparotomies performed specifically for a trauma patient are managed with damage control techniques [8]. *Persistent hypotension, acidosis* (*pH* < 7.2), *hypothermia* (*T* < 34°C), *and coagulopathy are strong predictors of the need to use damage control and open abdomen in trauma patients* [9]. However, damage control should not be an afterthought; it should be considered early in the decision process before the patient reaches a point of no return (before reaching the triad of death). Therefore before the surgery begins, there are many factors that should be considered: the available resources, the nature of the injuries, the experience of the surgeon, the clinical condition of the patient, and any comorbid conditions the patient might have [3].

During the damage control laparotomy, the primary goal of the trauma surgeon should be control of active hemorrhage (vascular shunting or ligation, direct packing, resection, etc.), followed by a strict control of contamination, and lastly temporary abdominal closure [7].

Despite the advancement of supportive care and the development of new sophisticated commercial devices for temporary abdominal closure, an open abdomen is still highly associated with serious postoperatively complications such as nutritional problems dealing with fluid and protein loss, loss of abdominal domain secondary to fascial retraction, frozen abdomen, and enteroatmospheric fistulas [5].

Following a damage control surgery, the abdomen should never be closed because of the high risk of intra-abdominal hypertension. The second stage within damage control procedures involves the stabilization of the physiological parameters in the intensive care unit, followed by the final stage of definitive surgical care in the operating room; this usually occurs within 24–48 h of the initial operation (preferably following the reversal of the lethal triad) [10].

2.1. Key points

- Open abdomen has become the preferred surgical method for patients whose physiological derangements do not allow the completion of an intended operation.
- Persistent hypotension, acidosis (pH < 7.2), hypothermia (T < 34°C), and coagulopathy are strong predictors of the need for damage control and open abdomen in trauma patients.
- Control of active hemorrhage must be the primary goal of the trauma surgeon during damage control laparotomy.
- Open abdomen is still associated with serious complications.
- The abdomen should never be closed because of the high risk of intra-abdominal hypertension.

3. Severe abdominal sepsis

The role of an open abdomen in the management of severe secondary peritonitis has been a controversial issue throughout time [3]. In severe secondary peritonitis, some patients may experience disease progression from severe sepsis and septic shock to progressive organ dysfunction, hypotension, myocardial depression, and coagulopathy, where a staged approach might be required [11].

If the patient is not in a condition where he can undergo definitive repair and/or abdominal wall closure (such as instability, elevated requirements of inotropics, etc.), *the intervention should be cut short* because of the suboptimal local conditions for healing [12]. In addition, *peritonitis and intra-abdominal sepsis can influence the intra-abdominal pressure* because of bowel distension, ascites, or parietal muscle contraction [13].

When facing the inability to completely control contamination in a single operation, it is recommended to postpone definitive intervention or anastomosis [14]. Extensive visceral edema and decreased abdominal wall compliance may increase the risk of developing abdominal compartment syndrome; therefore, primary fascial closure should not be attempted and the abdomen should be left open [13]. *Following the first* 24–48 h *after the initial surgery, the patient should be taken back to the operating room* for reoperation, lavage, drainage, source control, and if its feasible [14] the closure of the abdominal wall.

The CIAOW study reports that patients with abdominal sepsis have been shown to have worse outcomes after an open abdomen, with an increased incidence of fistula formation, intra-abdominal abscesses, and a higher-delayed primary closure rate [15, 16]. However, there is no definitive data or strong recommendation regarding the use of open abdomen in the face of severe peritonitis. Therefore, *when using an open abdomen approach under these circumstances, caution and individualization of patients should be the priority* [9].

3.1. Key points

- The role of an open abdomen in the management of severe secondary peritonitis has been a controversial issue.
- If the patient is not in a condition to undergo a definitive repair, the intervention should be cut short (hemodynamic instability, elevated requirements of inotropics, or insulated multi-organic failure).
- Peritonitis and intra-abdominal sepsis can influence the intra-abdominal hypertension.
- Following 24–48 h after the initial surgery, the patient should be taken back to the operating room.
- Caution and individualization of patients should be exercised when using open abdomen in severe abdominal sepsis.

4. Abdominal compartment syndrome

Intra-abdominal hypertension and abdominal compartment syndrome are commonly encountered among surgical and nonsurgical critically ill patients. Intra-abdominal hypertension is defined as a sustained pathologic increase in intra-abdominal pressure greater than or equal to 12 mm Hg. Abdominal compartment syndrome is defined as a sustained increase in intra-abdominal tension ≥20 mm Hg that is associated with new organ dysfunction or failure [3, 17].

$$\begin{aligned}\text{Abdominal perfusion pressure (APP)} &= \text{mean arterial pressure (MAP)} \\ &\quad - \text{intra-abdominal pressure (IAP)}\end{aligned} \tag{1}$$

Intra-abdominal hypertension can lead to tissue hypoperfusion, especially of the abdominal viscera, as well as organ dysfunction. Uncontrolled intra-abdominal hypertension that exceeds 25 mm Hg can cause abdominal compartment syndrome, which is a potentially lethal complication. It is characterized by cardiorespiratory and renal dysfunction, as well as bacterial and toxin intestinal translocation and intracranial hypertension [18].

Abdominal compartment syndrome develops as a result of alterations in perfusion related to intra-abdominal hypertension. It can be classified as primary if it is the result of a pathophysiologic process within the abdominopelvic cavity. It can be caused by bleeding, acute accumulation of ascites, a rapidly growing tumor or another type of mass, retroperitoneal edema, even the packing of visceral injuries, etc. Secondary abdominal compartment syndrome refers to the development of abdominal compartment syndrome in the absence of a primary abdomino-pelvic process [5].

The organ dysfunction that can be seen with abdominal compartment syndrome is usually recognized by the changes in lung and renal function. As abdominal compartment syndrome develops, the pulmonary dynamics change, tidal volumes decrease or, if mechanical ventilation is being used, an increase in peak pressure can be observed with similar tidal volumes. Renal dysfunction can be seen when there is a decrease in urine output caused by decreased renal perfusion as the renal vein is compressed due to the increased abdominal pressure. Other organs can display changes after abdominal compartment syndrome including but not limited to the heart and brain [2]. Intra-abdominal hypertension and abdominal compartment syndrome can also generate changes in other intra-abdominal organs [19].

All patients in the intensive care unit should have measurements of their intra-abdominal pressure because the real incidence of abdominal compartment syndrome in the intensive care unit remains sub-diagnosed, and in some cases it is still unknown. When abdominal compartment syndrome is suspected, bladder pressures should be measured. This is accomplished by instilling a small amount of sterile saline into the bladder and attaching a Foley tube to a pressure transducer [2]; according to the findings, the following steps will be decided and a treatment will be administered (**Table 1**).

Management of this condition requires a multidisciplinary approach by the surgeon and the intensive care unit team, taking in account a specific staged process [5] (**Figure 1**).

There are four main principles when it comes to the management of intra-abdominal hypertension: first of all, serial monitoring of intra-abdominal pressure should be taken every 4–6 h; optimization of systemic perfusion and organ function in the patient with an increased intra-abdominal pressure; medical procedures to reduce intra-abdominal pressure that are institution of specific such as sedation, analgesia, or neuromuscular blockade, and prompt surgical decompressive laparotomy for refractory intra-abdominal hypertension [3] (**Figure 2**).

Medical interventions include sedation to improve abdominal wall compliance, as well as the placing of a nasogastric tube for gastric drainage, removing intraperitoneal fluid collections if they are present, limiting intravenous fluids if possible, diuresis, and also allowing hypercarbia by reducing tidal volumes. *Although all these interventions are promising, the only solution for ACS is decreasing the pressure by performing a decompressive laparotomy* [2, 3, 17, 20].

Intra-abdominal pressure (IAP)
Normal → 5–7 mm Hg
Intra-abdominal hypertension grade I → 12–15 mm Hg
Intra-abdominal hypertension grade II → 16–20 mm Hg
Intra-abdominal hypertension grade III → 21–25 mm Hg
Intra-abdominal hypertension grade IV → > 25 mm Hg

Table 1. Final 2013 consensus definitions of the World Society of the Abdominal Compartment Syndrome [20].

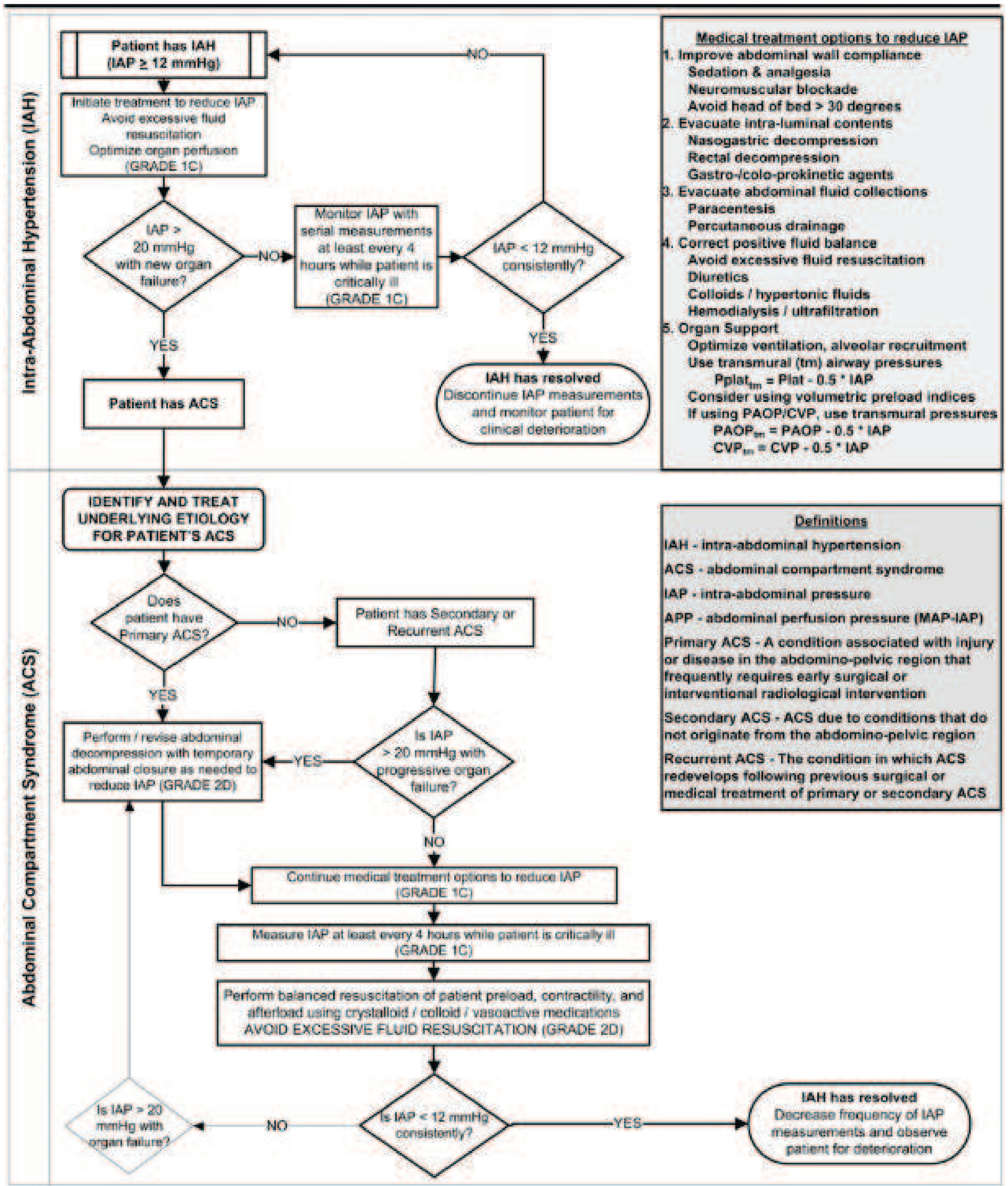

Figure 1. Intra-abdominal hypertension (IAH)/abdominal compartment syndrome (ACS) management algorithm. IAP, intra-abdominal pressure [17].

The main goals of decompressive laparotomy include reduction of the increased IAP in order to stop organ dysfunction, allow for a continued expansion of abdominal viscera during ongoing resuscitation, provide temporary abdominal coverage until the disease process resolves, prevent fascial retraction, and to allow a means for continued evacuation of fluid [3].

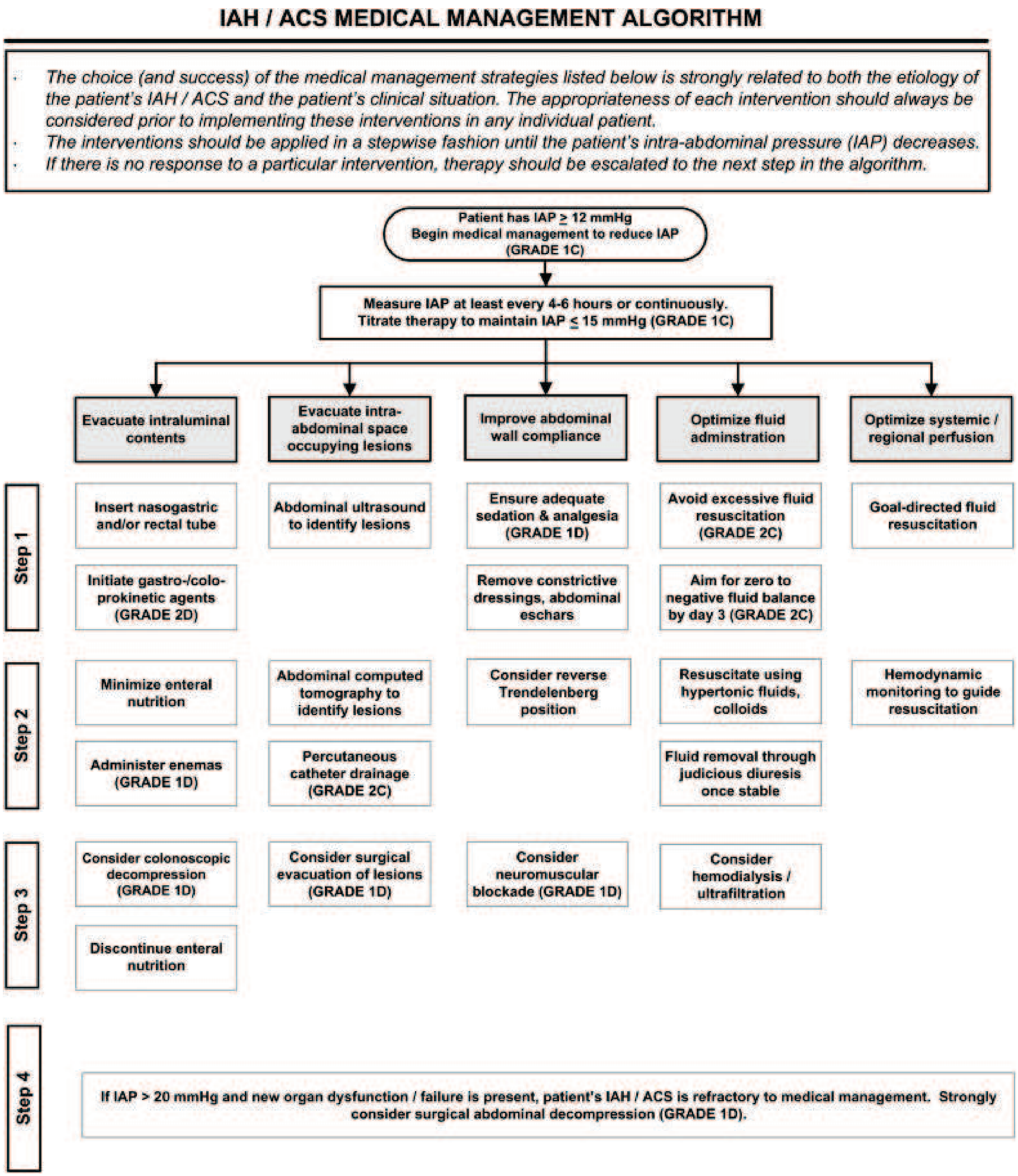

Figure 2. Intra-abdominal hypertension (IAH)/abdominal compartment syndrome (ACS) medical management algorithm. IAP, intra-abdominal pressure [17].

4.1. Key points

- IAH and ACS are commonly encountered among both surgical and nonsurgical critically ill patients.

- Abdominal perfusion pressure (APP), mean arterial pressure (MAP), intra-abdominal pressure (IAP).
- IAH can lead to tissue hypoperfusion, especially of the abdominal viscera, and organ dysfunction.
- Abdominal compartment syndrome develops as a result of alterations in perfusion related to IAH.
- All patients in the intensive care unit should have measurements of intra-abdominal pressure because the incidence of this entity remains sub-diagnosed and still unknown in some cases.
- The challenging situation to manage requires a multidisciplinary approach by the surgeon and the ICU team in a specific staged process.
- Although medical interventions are possible, the only solution for ACS is decreasing the pressure by decompressive laparotomy.

5. Management of the open abdomen

After the clinical scenarios that were just reviewed, *life-saving, decompressive laparotomy and temporary abdominal closure with future restoration of anatomic continuity of the abdominal wall* [21] *are frequently needed*. The chance of achieving one of the most important outcomes, the delayed primary fascial closure, depends on the severity of the underlying etiology [4]. While the management of an open abdomen has surely evolved over the last years, numerous strategies for temporary abdominal closure of an open abdomen have been described in the literature.

Besides prevention of evisceration, temporary abdominal closure can also facilitate subsequent access to the abdominal cavity and prevents retraction of the skin and fascia [4]. The ideal temporary abdominal closure should have some very specific qualities: it should be easy to apply and remove, it should allow rapid access to a surgical second look, it should drain secretions, it should ease primary closure and should have acceptable morbidity and mortality, it should allow easy nursing, and last but not least, it should be readily available and cheap [5] (**Table 2**).

Since the late 1970s and during the 1980s, abdominal dressings for an open abdomen were quite simple, and the treatment was centered only on the protection and control of the bowel that can be found outside the abdomen (nonabsorbable meshes were used, but these led to a high rate of intestinal fistulation) [5]. In the mid-1980s, a zipper was added to the mesh in order to make the process of re-exploration easier [22].

Throughout the years, the surgeons moved on from protection of the ileus to the preservation of the peritoneal space and the prevention of lateral retraction of the fascia, which are the most critical obstacles when dealing with the reconstruction of the abdominal wall at the end of the treatment [5].

For quick abdominal closure in damage control procedures, skin approximation with towel clips or running suture has been suggested in patients in extremis [3]. Another easy method is

1. Skin approximation with towel clips or running suture
2. Bogota bag
3. Synthetic meshes
4. Velcro or zipper-type synthetic materials (Wittmann patch, Starsurgical)
5. Negative-pressure dressing
a. Vacuum pack (Barker technique)
b. Vacuum-assisted closure (VAC Therapy, KCI)
c. Abthera™ system (KCI)

Table 2. Techniques for temporary abdominal wall closure [3].

the plastic silo, also known as the Bogotá bag, with a nonadherent plastic sheet, usually from a sterile 3 liter urology irrigation bag, sutured to the edges of the skin [5].

In 1995 the vacuum pack technique was described, where a perforated plastic sheet is used to cover the viscera and then sterile surgical towels are placed on the wound; a surgical drain is then connected to a continuous negative pressure that is placed on the towels, and everything is covered by an airtight seal; the dressing should be changed every 2–3 days in the operative room but could also be changed in the ICU [5, 22].

The vacuum pack was then developed with using a negative-pressure dressing system that includes a polyurethane foam covered with a protective fenestrated nonadherent layer tubing, a canister, and a computerized pump [3]. It has a few advantages, such as a reduced need for frequent dressing changes, increased vascularity of the wound, decreased bacterial counts, and an extended opportunity for definitive fascial closure [5].

In their systematic review and meta-analysis, Cirocchi et al. support the use of negative-pressure wound therapy in the temporary abdominal closure technique used to care for an open abdomen, concluding that negative-pressure wound therapy is associated with a better outcome than no negative-pressure wound therapy [23].

There is a new strategy that combines negative-pressure wound therapy with a mesh-mediated fascial traction tension. In a systematic review with 4358 patients, Atema et al. reported that negative-pressure wound therapy was the most frequently described temporary abdominal closure technique. The highest weighted fascial closure rate was found in series describing negative-pressure wound therapy with continuous mesh or suture-mediated fascial traction and dynamic retention sutures. Additionally, in a series applying negative-pressure wound therapy without fascial traction, a weighted fistula rate of 14.6% was seen, but when negative-pressure wound therapy was combined with continuous suture or mesh-mediated fascial traction, the fistula risk dropped to 5.7% [4].

Another implementation of the system was introduced by the Abthera™; it consists of a fenestrated plastic sheet with foam sponges that extend in a circular pattern, which is then placed over the viscera encompassing the paracolic gutters and the pelvis; foam sponges are placed on top of the protective layer. Furthermore, an adhesive drape covers the wound and extends over the skin. Suction tubing is attached to a portable suction device to create negative pressure [24].

The three main negative-pressure therapy modalities (Barker, VAC abdominal dressing system, Abthera™) have different mechanical properties, which may affect treatment outcomes. The most important difference between all of these modalities is the distribution pattern of the preset negative pressure [3]. Sammons applied a negative pressure of 125 mmHg to these three systems and measured the pressures in different areas of the dressing, concluding that pressure distribution of Abthera™ therapy was significantly superior to that of the Barker vacuum packing in all three measure zones and in medial and distal zones when comparing with the VAC system [25].

In the World Journal of Emergency Surgery Guidelines (2018), they recommend that negative-pressure wound therapy along with continuous fascial traction is the preferred method for temporary abdominal closure (Grade 1B). Temporary abdominal closure without negative-pressure wound therapy (e.g., mesh alone, Bogota bag) should NOT be used for the purpose of temporary abdominal closure, because of the low-delayed fascial closure rate and the significant intestinal fistula rate that often accompanies the method (Grade 1B) [9, 12].

The best and the right way to manage a patient with an open abdomen is still unclear: the technique is relatively new, and in the literature, the data and the casuistic reported are too varied and too heterogeneous to assess properly [5].

Early fascial and/or abdominal definitive closure should be the strategy for managing an open abdomen once any requirements for ongoing resuscitation have ceased, the source control has been definitively reached, there are no concerns regarding intestinal viability, no further surgical re-exploration is needed, and there are no concerns for abdominal compartment syndrome (Grade 1B) [9].

In many patients, early definitive fascial closure may not be possible because of the persistent bowel edema or intra-abdominal sepsis. In these cases, progressive closure should be attempted when there is a return to the operating room for a washout or dressing change, by placing a few interrupted sutures at the top and bottom of the fascia defect [3] with each new procedure.

Definitive closure of the abdominal wall has to be achieved as soon as possible. Different techniques can be applied in different settings: direct closure with dynamic traction techniques in early closure with little fascial gap, component separation, rotational flaps, the use of prosthetic or biologic mesh, etc.; nevertheless, a planned ventral hernia has to be considered if severe and persistent contamination of the peritoneal cavity is present [26].

5.1. Key points

- Life-saving decompressive laparotomy and temporary abdominal closure with later restoration of anatomic continuity of the abdominal wall are frequently needed.
- Besides prevention of evisceration, temporary abdominal closure can facilitate regaining access to the abdominal cavity and prevents retraction of the skin and fascia.

- We count with different techniques for temporary abdominal closure like skin approximation with towel clips or running suture, Bogota bag, synthetic meshes, velcro or zipper-type synthetic materials, or negative-pressure dressing.
- The best and the correct management of a patient with open abdomen is still unclear: the technique is relatively new, and in the literature, the data and the casuistic reported are too various and too heterogeneous to assess.
- Definitive closure of the abdominal wall has to be obtained as soon as possible. Different techniques can be applied for different settings.

6. Complications

Although the OA has addressed some serious and potentially lethal problems related to early closure of the abdomen, this technique is also *associated with significant complications, including wound infection, fluid and protein loss, a catabolic state, loss of abdominal wall domain, and development of enteroatmospheric fistula* [10].

The appearance of enteric contents from an abdominal incision is a devastating complication and can be emotionally distressing for both the patient and the surgeon. *Enteroatmospheric fistulas range from easily controlled low-output colocutaneous fistulas to high-output enteroatmospheric fistulas* that require a prolonged nutritional support, specialized wound care, and complex reoperative surgery [27]. The overall incidence of this complication is about 5%. However, in the chronically open abdomen, the incidence increases to about 15% [3].

Preemptive measures to prevent enteroatmospheric fistula and frozen abdomen are crucial (i.e., early abdominal wall closure, bowel coverage with plastic sheets, omentum or skin, no direct application of synthetic prosthesis over bowel loops, no direct application of negative-pressure wound therapy on the viscera, and deep burying of intestinal anastomoses under bowel loops) [12].

In some cases, numerous enteroatmospheric fistulas may develop, and the constant leak of enteric contents on the open abdomen aggravates the inflammation and encourages the formation of new fistulas [3]. Enteroatmospheric fistula management should be tailored according to patient condition, fistula output and position, and anatomical features (Grade 1C) [9, 12].

Enteric fistula management is composed of three phases: recognition and stabilization of the patient, anatomical definition and decision-making, and definitive operation [28].

Enteroatmospheric fistula is a life-threatening condition requiring longitudinal care for many months. A spectrum of vexing clinical problems ranging from hypovolemic shock to malnutrition to complex abdominal wall reconstruction challenges the skill of even highly experienced surgeons. *High-output fistulas and EAFs are best managed in centers providing comprehensive care of intestinal failure* [29].

6.1. Key points

- Open abdomen is associated with significant postsurgical complications, including wound infection, fluid and protein loss, a catabolic state, loss of abdominal wall domain, and development of enteroatmospheric fistula.
- Enteroatmospheric fistula can range from an easily controlled low-output colocutaneous fistula to a high-output enteroatmospheric fistula.
- Enteric fistula management is comprised of three phases: recognition and stabilization of the patient, anatomical definition and decision-making, and finally the definitive operation.
- High-output fistulas and EAFs are best managed in medical centers that provide comprehensive care of intestinal failure.

Author details

Juan José Santivañez Palomino[1]*, Arturo Vergara[2] and Manuel Cadena[2]

*Address all correspondence to: juan.santivanez@urosario.edu.co

1 Department of Surgery, Fundación Santa Fe de Bogotá, Colombia

2 Department of Metabolic Support and General Surgery, Fundación Santa Fe de Bogota, FACS, Universidad Los Andes, Colombia

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