The Management of the Open Abdomen - A Literature Review

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Rezumat

Managementul abdomenului deschis - recenzie a literaturii

O componentă esențială a conceptului „Damage control surgery”, laparostomia, este procedura prin care abdomenul este abandonat în mod deliberat deschis, conținutul visceroperitoneal fiind protejat temporar prin multiple mijloace tehnice. Clasificare actuală: Grad 1, fără aderențe viscero-parietale sau fixitate a peretelui abdominal (lateralizare), împărțit în: 1A curat, 1B contaminat și 1C fistulă enterală; Gradul 2, care dezvoltă fixare se împarte în: 2A curat, 2B contaminat și 2C fistula enterală; Gradul 3, „abdomen înghețat”, se împarte în: 3A curat și 3B contaminat; Gradul 4, definit ca fistulă entero-atmosferică, este o fistulă permanentă asociată cu prezența țesutului de granulație și a unui “abdomen înghețat”. Indicațiile abdomenului deschis sunt: intervenția chirurgicală de control al leziunilor, sindromul de compartiment abdominal, sepsisul peritoneal, pancreatita acută severă și urgențele vasculare. Închiderea temporară a abdomenului se poate realiza prin următoarele metode: închidere a tegumentului, „Bogota bag”, tehnica Opsite Sandwich, plasă sintetică absorbabilă, plasă neabsorbabilă sau fermoar (zipper) comercial, “vacuum assisted closure” (VAC), fiecare cu propriile avantaje și dezavantaje. În ceea ce privește închiderea definitivă, aceasta poate fi realizată în majoritatea cazurilor prin tehnici care folosesc plase neabsorbabile. Tehnica de separare a componentelor peretelui abdominal, anterioară sau posterioară, ar trebui considerată procedura de reparare electivă în defectele parietale după laparostomie. Deși au fost publicate mai multe studii, încă nu există un consens în literatura de specialitate cu privire la poziționarea materialului protetic în raport cu planurile parietale. Unii autori sugerează rezultate mai bune (față

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de rata de recidivă și complicații) pentru implantarea în poziția “sublay”. Abdomenul deschis este un instrument important în arsenalul intervenției chirurgicale de urgență. Clasificarea, indicațiile, metodele de închidere temporară abdominală, închiderea fascială definitivă precum și managementul fistulelor enterocutanate evoluează, de aceea este necesară actualizarea permanentă în raport cu noile achiziții tehnice și rezultatele studiilor factuale.

Cuvinte cheie: abdomen deschis, laparostomie, vacuum asisted closure, fistulă enterocutanată, închidere temporară abdomen

Abstract

An essential component of the concept of "Damage control surgery", laparostomy is the procedure by which the abdomen is deliberately abandoned open, the visceroperitoneal contents being temporarily protected by multiple technical means. Actual classification: Grade 1, without visceroparietal adhesions or fixity of the abdominal wall (lateralization), divided into: 1A clean, 1B contaminated and 1C enteral fistula (cutaneous skin is considered clean); Grade 2, which develops fixation is subdivided into: 2A clean, 2B contaminated and 2C enteral fistula; Grade 3, "frozen abdomen", is divided into: 3A clean and 3B contaminated; Grade 4, defined as entero-atmospheric fistula, is a permanent fistula associated with the presence of granulation tissue and a frozen abdomen. Indications of the open abdomen are: damage control surgery, abdominal compartment syndrome, peritonitis, severe acute pancreatitis, vascular emergencies. Temporary abdominal closure may be achieved by following methods: skin only closure, "Bogota bag", oposite Sandwich technique, absorbable mesh, non-absorbable mesh or commercial zipper, vacuum asisted closure, each with its own advantages and disadvantages. Regarding the definitive closure this can be achieved by non mesh and mesh mediated techniques. Component separation technique anterior and posterior should be considered the elective repair procedure in parietal defects after laparostomy. Although several studies have been published, there is still no consensus in the literature on the positioning of prosthetic material in relation to parietal planes. Some authors suggest better results (relative to the rate of recurrence and complications) for implantation in the "sublay" position. Open abdomen is an important tool in the arsenal of the emergency surgery. Classification, indications, methods of temporary abdominal closure are evolving, as well as management of enterocutaneous fistulas and fascial closure, therefore permanent update is necessary to offer patients the best care.

Key words: open abdomen, laparostomy, vacuum asisted closure, enterocutaneous fistula, temporary abdominal closure

Introduction

An essential component of the concept of "Damage control surgery", laparostomy is the procedure by which the abdomen is deliberately abandoned open, the visceroperitoneal contents being temporarily protected by multiple technical means.

In the medical literature, the first description of the open abdomen belongs to Andrew McCosh in 1897 (1). Subsequently, Ogilvie describes "the use of a double sheet of light canvas sutured into place with interrupted catgut suture in abdominal war wounds that could not be closed primarily" (2). In 1979, Steinberg published the analysis of a series of

14 patients with diffuse peritonitis and septic condition where the abdomen was left open with gauze packs for 48-72 hours, the wall being permanently sutured later (3). In the early 1980s, in the context of severe abdominal sepsis, Duff et al proposed the open abdomen technique as an extreme solution, with a mortality rate of 39% considered acceptable compared to the final primary closure of the abdominal wall (4). After 1990, correlated with the understanding of the pathophysiology of the abdominal compartment syndrome (ACS) and the promotion of the damage control strategy in the management of the polytrauma patient, multiple techniques of temporary closure of the abdomen appear: Bogota bag (5), marlex zipper (6,7), velcro adhesive sheets, absorbable and non-absorbable mesh (8) and sandwich technique (9).

Currently, the use of vacuum-assisted closure therapy techniques followed by early closure of the abdominal fascia is, in most randomized trials, the gold standard for preventing the evolutionary complications of the open abdomen (10,11).

Classification of Open Abdomen

In 2007, the World Society of the Abdominal Compartment Syndrome (WSACS) reviewed and developed a Guideline for the Management of ACS (12). Following this step of rethinking and standardizing the definitions, Björck proposes in 2009 the preliminary version of an open abdomen classification (13) which he amends in 2016 as a result of the experience

and results published by several surgical teams. Essentially, it is a revision of some items from the 2009 classification, changes highlighted comparatively in *Table 1* (14).

The purpose of this classification is the evolutionary assessment of the patient's clinical status, the standardization of guidelines and recommendations for open abdomen management and last but not least the homogeneous assessment of research results communicated on various samples of patients with complex lesions and various comorbidities. The following amendments have been proposed: Grade 1, without visceroparietal adhesions or fixity of the abdominal wall (lateralization), divided into: 1A clean, 1B contaminated and 1C enteral fistula - cutaneous skin is considered clean); Grade 2, which develops fixation is subdivided into: 2A clean, 2B contaminated and 2C enteral fistula; Grade 3, "frozen abdomen", is divided into: 3A clean and 3B contaminated; Grade 4, defined as entero-atmospheric fistula, is a permanent fistula associated with the presence of granulation tissue and a frozen abdomen.

Indications of Open Abdomen

In the broader context of the Damage Control Surgery (DCS) strategy, there are multiple situations that causally and pathophysiologically justify the use of the open abdomen (OA) as an extreme measure in the therapeutic algorithm of life-threatening conditions. This concept is configured to achieve several major objectives: control of peritoneal septic bleeding and

Table 1. Open abdomen classification system (14)

2009 classification system	Amended classification system
1A Clean OA without adhesions between bowel and abdominal wall or fixity (lateralization of the abdominal wall)	1A Clean, no fixation
1B Contaminated OA without adherence/fixity	1B Contaminated, no fixation 1C Enteric leak, no fixation
2A Clean OA developing adherence/fixity	2A Clean, developing fixation
2B Contaminated OA developing adherence/fixity	2B Contaminated, developing fixation 2C enteric leak, developing fixation
3 OA complicated by fistula formation	3A Clean, frozen abdomen 3B contaminated, frozen abdomen
4 Frozen OA with adherent/fixed bowel, unable to close surgically, with or without fistula	4 Established enteroatmospheric fistula, frozen abdomen

contamination, prevention of abdominal compartment syndrome (ACS) and facilitating re-exploration through a "planned re-laparotomy" (15).

Certainly, the very good results of the intensive support measures, the development of more and more efficient commercial devices in Temporary Abdominal Closure (TAC) and the prevention of specific complications, have contributed to the widening of indications in traumatic and non-traumatic pathology (16).

Open Abdomen in Trauma

In polytrauma patients, persistent hypotension, acidosis, hypothermia ($T < 34^{\circ}\text{C}$) and coagulopathy are predictors of severity requiring a Damage-control laparotomy and performing a laparostomy (WSES Guidelines 2018 - Grade 2A).

The risk factors that can lead to the installation of compartment syndrome (ACS) are: the presence of retroperitoneal hemorrhage or packing in major lesions of the parenchymal viscera with the impossibility to control the hemorrhagic source; the presence of post-traumatic ileus; decreased parietal compliance in obese patients or grade 3 parieto-abdominal burns; persistence of visceral edema following excessive volume resuscitation (17). Other factors have been described in the genesis of ACS: associated liver cirrhosis and respiratory failure (18). In this context, the open abdomen (OA) remains the saving gesture concomitant with other procedures in the therapeutic algorithm: nasogastric aspiration, colonic decompression, prokinetic agents, adequate mechanical ventilation, sedation or neuromuscular blockade, control of volume resuscitation (18,19,20).

Scheduling a "second-look operation" may be another indication of keeping the abdomen open in the context in which the index intervention has been stopped or shortened for hemorrhagic reasons and/or shock; when there are obvious signs of evolutionary enteral ischemia that have required resections without anastomosis and digestive continuity is expected to be restored after 24-72 hours, but

also when the packing material must be removed (15).

In most cases with enteral lesions (contusions or penetrating trauma) when the diagnosis is delayed or when anastomotic dehiscence occurs there is also abdominal sepsis, a lesional context when the indication of an open abdomen becomes perfectly justified (16).

The presence of military conflicts and the use of an arsenal that includes high-speed weapons, face emergency surgery with complex destructive visceral or abdominoparietal injuries, with high loss of muscular-aponeurotic head and where the reasonable solution remains the open abdomen and a way to temporarily close (Temporary abdominal closure) until reconstructive procedures become feasible (21).

Open Abdomen in Non-Trauma Patients

Peritonitis

In severe abdominal sepsis, OA and the staging of surgical procedures remain a strategy validated by at least 3 conditions. First of all, the objective inability to control the source of septic contamination through a single operation (22). The second eventuality is the state of shock and major metabolic imbalances that make it impossible to continue the operation or practice digestive anastomoses (23). The last argument is the significant visceral edema that increases the risk of ACS and justifies OA and a temporary closure technique (TAC) (24).

Severe acute pancreatitis

Beginning in the 1970s, most surgeons understood that removal of peripancreatic, necrotic, and infected tissue was difficult to achieve in a single operative stage, which is why they proposed OA and drainage of the collection resembling an abscess with a different location until final control of the septic source. It has been shown that the still high rate of mortality in severe forms of pancreatitis is due to the non-recognition of conditions leading to ACS and multivisceral insufficiency (MOF) as

well as the random, non-standardized application of drainage techniques (25,26).

Peripancreatic necrosis infection remains a major indication for surgical necrosectomy when percutaneous drainage techniques are incomplete (27) but never performed earlier than 4-6 weeks (walled-off pancreatic necrosis is expected) (28).

If ACS requires OA in the first days after the onset of pancreatitis, no exploration of the peripancreatic space is warranted, as there is a risk of infection with sterile necrosis and the onset of uncontrollable bleeding (29).

Vascular emergencies

Open abdomen (OA) is recommended as a highly factual procedure in rupture of the aortic aneurysm (Grade 1C) and considered as a strategy associated with surgical management of mesenteric ischemia (Grade 2C) (WSES Guidelines 2018).

The combination of the hemorrhagic shock with the massive transfusions contributes to the appearance of an important edema of the retroperitoneal, mesenteric and parieto-enteral space, the appearance of ascites and ACS. The onset of compartment syndrome is reported in 8-20% of cases with a mortality rate of 30-50% (30).

Mesenteric ischemia (arterial/venous) may be a consequence of thromboembolism or regional hypoperfusion, and principles of therapeutic management include restoration of intestinal perfusion and control of enteral viability with possible resection of necrotic areas. In some prospective studies, the incidence of ACS is significantly reduced when OA is indicated prophylactically. Although the indications are not yet standardized, the impossibility of closing the parietal without tension, the loss of more than 5l of perioperative blood and the use of the occlusive aortic balloon, may be justified indications in major vascular emergencies (31,32). When using a vascular graft, the risk of its infection in OA conditions remains very low (33).

Another indication of OA in the management of mesenteric ischemia is the facilitation of a second-look laparotomy for the assess-

ment of enteral viability and / or the practice of an anastomosis resection (33).

Fascial Closure

Essentially, the abdominal fascia should be closed when the risk of abdominal compartment syndrome (ACS) is fined, the source of abdominal sepsis is controlled, and iterative re-laparotomy procedures are no longer anticipated.

Chronologically, the fascial closure procedure can be performed in 2 moments, defined in the medical literature as early closure (early fascial closure) in the first 4-7 days before the moment of laparostomy and late closure (delayed fascial closure) completed after 7 days from the index operation (34).

Priority, after achieving the objectives that validated the indication for laparostomy, remains the early and definitive closure of the abdominal fascia to prevent enteroatmospheric fistula and avoid fascial retraction with the appearance of large postoperative events.

Chen Y et al (2014) comparatively analyze in a systematic review and meta-analysis (35) the advantages of early closure over delayed fascial closure by emphasizing a lower mortality rate (12.3% vs 28%) and a decrease in complications postoperative (RR, 0.68, $p < 0.0001$).

Temporary Abdominal Closure

Ideally, this procedure should protect the viscero-abdominal contents, prevent evisceration, remove intra-peritoneal septic exudate, prophylaxis of enterocutaneous fistula, preserve muscle-aponeurotic capital, facilitate planned laparotomies and achieve optimal conditions (9,21,36,37). Unfortunately, none of the temporary closure techniques can achieve these goals alone.

In the last 20 years, multiple surgical procedures to complete the temporary closure (TAC) have been proposed, the option to one or the other of which being a continuous and responsible challenge of the surgical team. The decision must be adapted to the patient's

biological condition, prevention of post-laparostomy complications and available financial resources (38,39). Temporary closure techniques (TACs) can be classically grouped into 3 categories: skin-only closure, patch closure and vacuum-assisted closure (40).

In 2015, Sartelli and a multicenter team published in the *World Journal of Emergency Surgery* (11) a critical comparative analysis of TAC procedures that is illustrated in *Table 2*.

Skin-only closure uses either a single skin suture (frequently surjet) or operator field tweezers (towel clips). Although several recent publications (consensus conferences and guidelines) propose the abandonment of this technique (21) attributing to the procedure ischemic necrotic and infectious skin complications, a relatively high rate of persistent ACS (18.5%) and a moderate risk of enterocutaneous fistula (6%), in hostile and economically precarious environments can offer a number of advantages: fast closure, cheap, low mortality rate, prevents excessive loss of intraperitoneal fluids while maintaining visceral temperature.

The "Bogota bag" technique imagined by Oswaldo Borraez in 1984, popularized in the literature by Mattox (41), has similar advantages to skin-only closure but does not prevent

muscle-aponeurotic retraction resulting in major difficulties of late parietal closure (Delayed fascial closure). The primary closure rate reported in the literature varies within very wide limits, 12-82% (36).

Patch-closure techniques (Mesh, Witmann patch or Zipper) create parietal tension-free and facilitate intraperitoneal re-exploration. The prosthetic material can be removed in re-laparotomies and the parietal tension can be adjusted by median plication. Classically the adjustments are made every 24-48 hours until the fascial edges are close to about 2-4 cm offering the possibility of primary closure (42,43). The use of devices for dynamic modeling of fascial tension allowed the primary closure to be achieved at intervals exceeding 50 days (44).

Various types of materials have been proposed, starting with polypropylene (which is attributed to an increased rate of enterocutaneous fistula, continuing with polytetrafluoroethylene (ePTFE) less adherence to the visceral content and ending with absorbable meshes (polyglactin and polyglycolic acid) at a rate The use of non-absorbable TAC nets is associated with a primary closure rate of 33-89% (20).

Witmann describes in 1990 the technique

Table 2. Critical comparative analysis of TAC procedures (11)

Technique	Equipment	Advantages	Disadvantages
Skin only closure	Skin staples, towel clips or sutures	Cheap, available, minimises heat and fluid loss	Damage to the skin, risk of evisceration, no control of fluid loss, may develop ACS
"Bogota bag"	Sterile 3 litre saline bag cut and shaped and sutured to fascial edges	Cheap, available, minimises heat and fluid loss	Damage to the fascial edges, risk of evisceration, no control of fluid loss. Allows some assessment of intestinal viability
Opsite Sandwich technique	Polyethylene sheet, opsite dressings, abdominal packs, 2 suction drains and wall suction	Cheap, available, minimises heat and fluid loss is controlled and measurable	Incomplete fluid control and need for available wall suction
Absorbable mesh	Vicryl or similar MESH	Absorbable mesh, infection resistance, protects from evisceration, can be skin grafted	High rate of subsequent incisional herniation
Non absorbable mesh or commercial Zipper	Commercial Whitmann patch	Abdominal re-exploration is easy, maintains abdominal domain, gradual abdominal closure possible	Commercial equipment required and repeated operation needed for closure
Vacuum assisted Closure	commercial kit	Prevents loss of abdominal domain, collects and monitors fluid loss, decreases ACS, no damage to skin and or abdominal fascia	Expensive commercial equipment required. Usually requires general anesthesia to change the kit

that bears his name using a Velcro patch (8) that facilitates the re-exploration of the peritoneal cavity through the slit that separates the 2 superimposed sheets in the middle. The method remains prohibitive in terms of costs (about 1440 USD / patient) with a primary closure rate of 65.7-100% and an incidence of entero-cutaneous fistula of 0-42% (43,45).

Zipper closure system published by Leguit in 1982 (46) allows the planned iterative exploration of the peritoneum with the indication of choice peripancreatic abscesses (47). The primary closure rate of the fascia varies between 50-100%.

Negative pressure therapy (NPT) is currently the most recommended method of temporarily closing the abdomen. In its classic sense proposed by Barker and Brock in 1995 (48) Vacuum pack is a "sandwich" technique in which the visceral block is covered with a polyethylene window foil, the overlying space delimited by the fascial edges, being filled with soft gauze fields and 2 drain pipes connected to the suction system, the tightness being made by an external adhesive foil (opposite sandwich technique). The method is inexpensive, easy to apply and manage, protecting the viscera, facilitating the outflow of septic fluids, preventing viscero-parietal adhesions and partially fascial retraction. Aspiration at a pressure of 100-150 mmHg is initiated for 48 hours continuously and then applied intermittently in conjunction with individual circumstances.

Barker reports in a study published in 2007 (49) a primary closure rate of 68.1% and an incidence of enterocutaneous fistula of 5%. VAC and ABThera commercial devices with minimal technical design changes (ABThera extends visceral draping to parachute gutters) achieve the same goal of fascial closure rate and fistula incidence but at significantly higher costs (ABThera sponge 350 USD and rental cost of suction machine 67.5 USD/day) (50). By using absorbent sponges, commercial NPWT devices have the advantage of reducing the indication of frequent change of soft material fields (used by the Barker technique).

Patients treated with Negative Pressure

Wound Therapy (NPWT) have been shown to reduce intestinal edema and increase local blood perfusion, which accelerates the growth of granulation tissue and reduces local microbial growth (51).

Superior results were obtained if the VAC was combined with the Dynamic Retention Suture (ABRA) technique. In a prospective study combining both methods, Pliakos in a sample of 111 patients reported (52) a primary closure rate of 76.6%, an incidence of entero-cutaneous fistula of 7.2% and a mortality of 29.7%. In the 2018 WSES Guide, Coccolini et al (7) recommend NPWT combined with fascial traction as the standard method in temporary closure (Grade 1B). Similarly, Atema et al in a systematic review including 4358 patients, reported in the series in which NPWT was associated with mesh or suture-mediated fascial traction procedures a significant decrease in the incidence of entero-cutaneous fistula to 5.7% compared to NPWT used. the only one where the rate was 14.6% (53).

In conclusion, the priority for the reduction of mortality, complications and length of hospitalization remains the definitive early closure of the abdomen, this desideratum being directly influenced by the quality of the postoperative management in the intensive care unit and the TAC procedure adopted.

Definitive Closure

In the situation of prolonging the condition of the open abdomen, the lateralization by retraction of the abdominal fascia causes large parietal defects that fortuitously require complex surgical solutions. (53)

From a surgical point of view, the options for permanent closure of the abdomen after laparostoma can be grouped into 2 categories: non-mesh-mediated closure techniques and techniques that use prosthetic material (mesh-mediated closure).

Non-mesh-mediated closure are techniques not recommended in temporary abdominal closure (WSES Guidelines). They are reserved for final closure only (Grade 2C) (15). In

this decision-making context, abdominal "components separation technique" should be considered the elective repair procedure in parietal defects consequent to laparostomy (54) with 75% success rate (55). Anatomically, the separation of the parietal components can be achieved by anterior or posterior approach.

In 1990, Ramirez et al proposed a technique for reconstructing large postoperative events with significant retraction of the fascial component, which they called the "Components separation technique." The intervention is based on the dissection and translation of the parietal planes in such a way that the coverage of the visceral mass is possible (54).

In the previous approach, the skin and subcutaneous tissue dissected from the anterior sheath of the right rectus abdominis and the aponeurosis of the external oblique, the latter being sectioned at a distance of 2 cm, laterally from the right sheath of rectus abdominis. Subsequently, the external oblique muscle is split from the internal one, as much as possible; another relaxation incision at the level of the inner edge of the right rectus abdominis muscle allows a good relaxation of the musculo-aponeurotic planes facilitating the median suture (*Fig. D*).

In the posterior approach, the right abdominal sheath is sectioned longitudinally allowing the cleavage between the posterior

sheet and the muscular body; subsequently at the wide edge of the right muscle, the transverse aponeurosis is incised with the separation of the internal oblique from the transverse muscle.

Despite the very good results, especially in the large parietal defects, with a recurrence of the eventration of only 16% (56), the technique also has some imputable elements. Excessive lateral mobilization of the skin and subcutaneous tissue on the fascial plane generates an anatomical space prone to seromas and / or hematomas that can become secondary infection. Second, the transection of perforating vessels emerging from the epigastric vessels at the time of superficial plane cleavage can lead to parchial ischemia and soft tissue necrosis of the midline. Last but not least, dissection and sliding of the skin and subcutaneous tissue on the fascial plane can become difficult in the pre-existence of enterostomies (57).

Mesh-mediated closure. The WSES guidelines (2018) stipulate that the use of non-resorbable nets in the definitive closure of laparostomy is not recommended or should be accepted only in situations where there is no other alternative (Recommendation Grade 1B) while biological nets are electively recommended for large parietal defects with local microbism in patients with co-morbidities (Grade 2B) (38).

Remote follow-up of patients using "biological mesh bridging" showed a relatively high rate of herniated recurrence in discordance with excellent short-term results in curing the parietal defect. The term "bridging technique" defines the interposition of the prosthetic material between the fascial edges when the retraction lateralization of the fascia does not allow suturing with the patient's native material. In fact, in the absence of a protective layer between the wall and the visceral contents, the non-resorbable material will generate, following the inflammatory response and local microbism, adhesions, visceral erosions and the risk of entero-atmospheric fistula (58).

In a recent meta-analysis, Sharrock et al. (59) report a recurrent eventration rate of

Figure 1. Component separation technique (54)
1 = skin and subcutaneous tissue, 2 = external oblique muscle,
3 = internal oblique muscle, 4 = transverse muscle
5 = right rectus abdominis muscle

51% one year apart highlighting real differences between trauma patients and those with laparostoma indication for severe abdominal sepsis.

In another meta-analysis and systematic review, Atema et al. (2016) report a recurrence rate of ventral hernia of about 30% when using biological material vs. 7% for non-resorbable prosthetic material, stating that the results may be affected by the heterogeneity of the samples included in the study (60).

The association of NPWT with a procedure that uses "biological bridging mesh" facilitates the appearance of tissue granulation and healing (61).

Both et al. comparing the use of prosthetic material as an adjunct to parietal reinforcement in primary fascial closure vs. "bridging technique" highlights a significantly higher recurrence for the 2nd sample (8 vs 56%; $p < 0.001$) (62).

Although several studies have been published, there is still no consensus in the literature on the positioning of prosthetic material in relation to parietal planes. Some authors suggest better results (relative to the rate of recurrence and complications) for implantation in the sublay position (63).

Management of Enteroatmospheric Fistula

The entero-atmospheric fistula (EAF) or exposed fistula is defined as a communication between the gastrointestinal tract and the atmosphere (64).

It is perhaps the most dramatic complication in the evolution of the open abdomen with direct implications for mortality, duration and hospitalization costs (65). The incidence of EAF varies in the literature from 4.5 to 25% in the open abdomen of traumatic indication (66) and from 5.7 to 17.2% in non-traumatic laparostomas (53).

In the prospective multicenter study using the AAST Open Abdomen Registry, Bradley et al. identifies a number of predictive factors in the appearance of EAF: large intestinal resections, excessive volume load ($> 5l/24h$),

increased number of intra-peritoneal re-examinations, remanence of intra-abdominal sepsis, iatrogenic lesions at initial dissection, presence of non-prosthetic material - absorbable in Temporary abdominal closure (TAC) and prolonged, unprotected exposure of the general mass (66,67).

Preventive measures logically derive from amending these conditions: early abdominal closure, covering the enteral mass with epiploon / skin in TAC, banning the use of non-resorbable prosthetic material in direct relation to the intestine or applying NPWT directly on the visceral mass (68,69).

A recent review (Bruhin et al.) highlights the high incidence of EAF in the open abdomen in abdominal sepsis compared to non-septic open abdomen (12.1% vs. 3.7%) (70). Similar findings are reported in the published series. by Tavusbay in 2014 (71) for laparostomy of abdominal sepsis where the incidence of EAF was 54.5% closure rate using NPWT was 22%, the average duration of VAC therapy was 43.6 days and mortality was 44.4%.

Classification of entero-atmospheric fistula (EAF) is essential in establishing the therapeutic algorithm. Schein and Decker proposed a location-related classification in 1991 (72), but the most complete remains the classification published by Di Saverio et al. In 2015 (73) based on anatomical location (proximal/distal), fistula flow (low, moderate, high), superficial or deep exposure and number of fistulous orifices (*Table 3*).

Some general considerations may be predictable for the evolution of fistula. Thus, a superficial exposure with distal intestinal

Table 3. Classification of enteroatmspheric fistula

Anatomic location	
Proximal	Stomach, duodenum, jejunum, proximal ileus
Distal	Distal ileus, colon
Output volume	
Low	<200 mL/24 h
Moderate	200-500 mL/24 h
High	> 500 mL/24 h
Location inside the open abdomen	
Superficial	Drains on top of a granulating abdominal wound
Deep	Drains intestinal content inside the peritoneal cavity

origin and low flow is more likely to close spontaneously than deep, multiple, high flow locations (74).

Based on these principles, the treatment must always be adapted to each patient, correlated with the biological status and characteristics of the fistula. Spontaneous closure is exceptional because the entero-atmospheric fistula has no anatomical trajectory and there is no vascularized tissue support to cover the fistulous orifice.

The main purpose of treatment should be to control the fistulous efflux and to facilitate the granulation of the underlying visceral bed. The essential components of the therapeutic strategy can be summarized in the acronym "SNAP": management of sepsis and skin, nutritional support, anatomical location and procedure to deal with the fistula (75).

Externalization and proximal surgical diversion of the fistula are practically impossible to achieve considering the mesenteric retraction, the inflammatory edema and the appearance of "frozen abdomen". For these reasons, EAF management should follow (73,74):

- output reduction by strictly parenteral feeding (at least in the first phase), proton pump inhibitors (PPI); the use of somatostatin / octreotide remains controversial,
- control and correction of hydro-electrolytic and acid-base imbalances,
- correction of hypercatabolic status.

Sepsis control

Protection of the visceral bed against the corrosive aggression of the intestinal secretions with the intention of granulation and preparation for the final treatment

Parenteral nutrition plays a key role in the management of these patients and should be initiated early by reducing local septic complications and balancing the nitrogen balance with protein supplements (WSES Guidelines 2018 - Grade 1C Recommendation).

Hypertabolic state is associated with muscle

proteolysis, impaired immune function and the appearance of MOF (76).

Multiple fistulous efflux diversion techniques and types of protective dressings have been described in the literature, customized according to the patient and the characteristics of the fistula: "Floating stoma", Fistula and VAC tube, Baby bottle nipple VAC, Fistula patch and Fistula plug, Suspension stoma conversion (77-81). Any fistula intubation maneuver is a serious error, the final effect not being the flow control but the enlargement of the fistulous orifice (69).

The latest consensus conferences propose NPWT in conjunction with accessory devices that isolate the fistulous tract as the method with the best results in closing the EAF. (WSES Guidelines 2018 - Grade 2A Recommendation).

Occasionally, the fistula of small size and eccentric at the level of the dehiscent area can be covered with slipped skin fascia / flap, realizing the healing premises through the overlying vascularized tissue (69).

In general, it is recommended that the definitive surgical closure of EAF be delayed for 6-12 months, during which time the inflammatory process and viscero-parietal adhesions are resolved, thus reducing the risk of enteral injury. The surgery must oblige to resect the intestinal segment that communicates with the fistula, to restore digestive continuity and to cover the enteral mass through a parietal reconstructive procedure (Components separation technique or split-thickness skin graft) (82).

Management of open abdomen has undergone some amendments of the classification. Indications are generally still the "classic" ones. Many methods are recognized and accepted for the temporary abdominal closure. Each has its own specific advantages and disadvantages, choice being made accordingly and to the specificity of each case. Definitive closure uses mesh and non mesh related techniques, both of them requiring a certain level of proficiency.

Conclusions

Open abdomen is an important tool in the arsenal of the emergency surgery. Classification, indications, methods of temporary abdominal closure are evolving, as well as management of enterocutaneous fistulas and fascial closure, therefore permanent update is necessary to offer patients the best care.

Conflict of Interest

The authors declare no conflicts of interests.

References

- McCosh AJ. The treatment of general septic peritonitis. *Ann Surg.* 1897; 25:687–97.
- Ogilvie WH. The late complications of abdominal war wounds. *Lancet.* 1940; 2:253–56.
- Steinberg D. On leaving the peritoneal cavity open in acute generalized peritonitis. *Am J Surg.* 1979;137:216–20.
- Duff JH, Moffat J. Abdominal sepsis managed by leaving abdomen open. *Surgery.* 1981;90(4):774–8.
- Kirshtein B, Roy-Shapira A, Lantsberg L, Mizrahi S. Use of the “Bogota bag” for temporary abdominal closure in patients with secondary peritonitis. *Am Surg.* 2007;73(3):249–52.
- Garcia-Sabrido JL, Tallado JM, Christou NV, Polo JR, Valdecantos E. Treatment of severe intra-abdominal sepsis and/or necrotic foci by an “open-abdomen” approach. Zipper and zipper-mesh techniques. *Arch Surg.* 1988;123(2):152–6.
- Hedderich GS, Wexler MJ, McLean AP, Meakins JL. The septic abdomen: open management with Marlex mesh with a zipper. *Surgery.* 1986;99(4): 399–408.
- Wittmann DH, Aprahamian C, Bergstein JM. Etappenlavage: advanced diffuse peritonitis managed by planned multiple laparotomies utilizing zippers, slide fastener, and Velcro analogue for temporary abdominal closure. *World J Surg.* 1990;14(2):218–26.
- Schein M, Saadia R, Jamieson JR, Decker GA. The “sandwich technique” in the management of the open abdomen. *Br J Surg.* 1986;73(5):369–70.
- Miller PR, Meredith JW, Johnson JC, Chang MC. Prospective Evaluation of Vacuum-Assisted Fascial Closure After Open Abdomen. *Ann Surg.* 2004; 239(5):608–16.
- Sartelli M, Abu-Zidan FM, Ansaloni L, Bala M, Beltrán MA, Biffl WL, et al. - The role of the open abdomen procedure in managing severe abdominal sepsis: WSES position paper. *World J Emerg Surg.* 2015;10:35.
- Cheatham ML, Malbrain MLNG, Kirkpatrick A, Sugrue M, Parr M, De Waele J, et al (2007) - Results from the International Conference Experts on Intra-Abdominal Hypertension and Abdominal Compartment Syndrome. *Recommendations. Intensive Care Med.* 2007;33(6):951–62.
- Björck M, Bruhin A, Cheatham M, Hinck D, Kaplan M, Manca G, et al. Classification, an important step to improve the management of patients with an open abdomen. *World J Surg.* 2009;33(6):1154–7.
- Björck M, Kirkpatrick AW, Cheatham M, Kaplan M, Leppäniemi A, De Waele JJ. Amended classification of the open abdomen. *Scand J Surg.* 2016; 105(1):5–10.
- Coccolini F, Biffl W, Catena F, Ceresoli M, Chiara O, Cimbani S, et al. The open abdomen, indications, management and definitive closure. *World J Emerg Surg.* 2015;10:32.
- Cothren Burlew C. The open abdomen: practical implications for the practicing surgeon. *Am J Surg.* 2012;204:826–35.
- Balogh ZJ, van Wessem K, Yoshino O, Moore FA. Post injury abdominal compartment syndrome: are we winning the battle? *World J Surg.* 2009; 33:1134–41.
- Holodinsky JK, Roberts DJ, Ball CG, Blaser AR, Starkopf J, Zygun DA, et al. Risk factors for intra-abdominal hypertension and abdominal compartment syndrome among adult intensive care unit patients: a systematic review and meta-analysis. *Crit Care.* 2013;17(5):R249.
- Dubose JJ, Scalea TM, Holcomb JB, Shrestha B, Okoye O, Inaba K, et al. Open abdominal management after damage-control laparotomy for trauma: a prospective observational American Association for the Surgery of Trauma multicenter study. *J Trauma Acute Care Surg.* 2013;74:113–20–2.
- Regner JL, Kobayashi L, Coimbra R. Surgical strategies for management of the open abdomen. *World J Surg.* 2012;36:497–510.
- Chiara O, Cimbani S, Biffl W, Leppäniemi A, Henry S, Scalea TM, et al. International consensus conference on open abdomen in trauma. *J Trauma Acute Care Surg.* 2016;80:173–83.
- Schein M. Surgical management of intra-abdominal infection: is there any evidence? *Langenbeck's Arch Surg.* 2002;387:1–7.
- Ordonez CA, Sanchez AI, Pineda JA, Badiel M, Mesa R, Cardona U, et al. Deferred primary anastomosis versus diversion in patients with severe secondary peritonitis managed with staged laparotomies. *World J Surg.* 2010;34:169–76.
- Plantevefe G, Hellmann R, Pajot O, Thirion M, Bleichner G, Mentec H. Abdominal compartment syndrome and intra-abdominal sepsis: two of the same kind? *Acta Clin Belg.* 2007;62 Suppl 1:162–7.
- Bradley III EL. Management of infected pancreatic necrosis by open drainage. *Ann Surg.* 1987;206:542–8.
- Bosscha K, Hulstaert PF, Hennipman A, Visser MR, Gooszen HG, van Vroonhoven TJMV, et al. Fulminant acute pancreatitis and infected necrosis: results of open management of the abdomen and “planned” reoperations. *J Am Coll Surg.* 1998;187:255–62.
- van Santvoort HC, Besselink MG, Bakker OJ, Hofker HS, Boermeester M, Dejong CH, et al. A step-up approach or open necrosectomy for necrotizing pancreatitis. *N Engl J Med.* 2010;362:1491–502.
- Werner J, Hartwig W, Hackert T, Buchler MW. Surgery in the treatment of acute pancreatitis – open pancreatic necrosectomy. *Scand J Surg.* 2005; 94:1130–4.
- Besselink MG, Van Santvoort HC, Boermeester MA, Nieuwehuijs VB, Van Goor H, Dejong CHC, et al. Timing and impact of infections in acute-pancreatitis. *Br J Surg.* 2009;96:267–73.
- Reite A, Soreide K, Ellingsen CL, Kvaløy JT, Vetrhus M. Epidemiology of ruptured abdominal aortic aneurysms in a well-defined Norwegian population with trends in incidence, intervention rate, and mortality. *J Vasc Surg.* 2015;61:1168–74.
- Ersryd S, Djavan-Gidlund K, Wanhainen A, Björck M. Abdominal compartment syndrome after surgery for abdominal aortic aneurysm: a Nationwide Population Based Study. *Eur J Vasc Endovasc Surg.* 2016;52:158–65.
- Acosta S, Wanhainen A, Björck M. Temporary abdominal closure after abdominal aortic aneurysm repair: a systematic review of contemporary observational studies. *Eur J Vasc Endovasc Surg.* 2016;51:371–8.
- Bruns BR, Ahmad SA, O'Meara L, Tesoriero R, Lauerma M, Klyushnenkova E, et al. Nontrauma open abdomens: a prospective observational study. *J Trauma Acute Care Surg.* 2016;80:631–6.
- Godat L, Kobayashi L, Costantini T, Coimbra R. Abdominal damage control surgery and reconstruction: World society of emergency surgery position paper. *World J Emerg Surg.* 2013;8(1):53.
- Chen Y, Ye J, Song W, Chen J, Yuan Y, Ren J. Comparison of outcomes between early fascial closure and delayed abdominal closure in patients with open abdomen: a systematic review and meta-analysis. *Gastroenterol Res Pract.* 2014;2014:784056.
- Huang Q, Li J, Lau WY. Techniques for abdominal wall closure after damage control laparotomy: from temporary abdominal closure to early/delayed fascial closure – a review. *Gastroenterol Res Pract.* 2016;2016:2073260.
- Khasawneh MA, Zielinski MD. Optimum methods for keeping the abdomen open. *Curr Trauma Reports.* 2016;2:189–95.
- Coccolini F, Roberts D, Ansaloni L, Ivatury R, Gamberini E, Kluger Y, et al. The open abdomen in trauma and non-trauma patients: WSES guidelines.

- World J Emerg Surg. 2018;13:7.
39. Kreis BE, de Mol van Otterloo AJ, Kreis RW. Open abdomen management: a review of its history and a proposed management algorithm. *Med Sci Monit*. 2013; 19:524-33.
 40. Milne DM, Rambhajan A, Ramsingh J, Cawich SO, Naraynsingh V. Managing the Open Abdomen in Damage Control Surgery: Should Skin-Only Closure be Abandoned? *Cureus*. 2021;13(6):e15489.
 42. Weinberg JA, George RL, Griffin RL, Stewart AH, Reiff DA, Kerby JD, et al. Closing the open abdomen: improved success with Wittmann Patch staged abdominal closure. *J Trauma*. 2008;65(2):345-8.
 43. Tieu BH, Cho SD, Luem N, Riha G, Mayberry J, Schreiber MA. The use of the Wittmann Patch facilitates a high rate of fascial closure in severely injured trauma patients and critically ill emergency surgery patients. *J Trauma*. 2008;65(4):865-70.
 44. Vertrees A, Greer L, Pickett C, Nelson J, Wakefield M, Stojadinovic A, et al. Modern management of complex open abdominal wounds of war: a 5-year experience. *J Am Coll Surg*. 2008; 207(6):801-9.
 45. Coccolini F, Montori G, Ceresoli M, Catena F, Ivatury R, Sugrue M, et al. IROA: International Register of Open Abdomen, preliminary results. *World J Emerg Surg*. 2017;12:10.
 46. Leguit P Jr. Zip-closure of the abdomen. *Neth J Surg*. 1982;34:40-1.
 47. Perez A, Hilvano S. Abdominal zippers for temporary abdominal closure in planned relaparotomies for peripancreatic sepsis: experience in a developing country. *J Hepatobiliary Pancreat Surg*. 2001;8:449-52.
 48. Brock WB, Barker DE, Burns RP. Temporary closure of open abdominal wounds: The vacuum pack. *Am Surg* 1995;61:30-35.
 49. Barker DE, Green JM, Maxwell RA, Smith PW, Mejia VA, Dart BW, et al. Experience with vacuum-pack temporary abdominal wound closure in 258 trauma and general and vascular surgical patients. *J Am Coll Surg*. 2007; 204(5):784-92. discussion 792-3.
 50. Frazee RC, Abernathy SW, Jupiter DC, Hendricks JC, Davis M, Regner JL, et al. Are commercial negative pressure systems worth the cost in open abdomen management? *J Am Coll Surg*. 2013;216(4):730-3; discussion 733-5.
 51. Kirkpatrick AW, Roberts DJ, Faris PD, Ball CG, Kubes P, Tiruta C, et al. Active negative pressure peritoneal therapy after abbreviated laparotomy: the intra-peritoneal vacuum randomized controlled trial. *Ann Surg*. 2015;262(1): 38-46.
 52. Pliakos I, Papavramidis TS, Mihalopoulos N, Koulouris H, Kesiosoglou I, Sapalidis K, et al. Vacuum-assisted closure in severe abdominal sepsis with or without retention sutured sequential fascial closure: a clinical trial. *Surgery*. 2010;148(5):947-53.
 53. Atema JJ, Gans SL, Boermeester MA. Systematic review and meta-analysis of the open abdomen and temporary abdominal closure techniques in non-trauma patients. *World Journal of Surgery*. 2015;39(4):912-925.
 54. Ramirez OM, Ruas E, Dellon AL. "Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study. *Plast Reconstr Surg*. 1990;86:519-26.
 55. Rasilainen SK, Mentula PJ, Leppäniemi AK. Components separation technique is feasible for assisting delayed primary fascial closure of open abdomen. *Scand J Surg*. 2016;105:17-21.
 56. de Vries Reilingh TS, van Goor H, Charbon JA, Rosman C, Hesselink EJ, van der Wilt GJ, et al. Repair of giant midline abdominal wall hernias: "components separation technique" versus prosthetic repair: interim analysis of a randomized controlled trial. *World J Surg Springer*. 2007;31:756-63.
 57. de Vries Reilingh TS et al - "Components separation technique" for the repair of large abdominal wall hernias - *J Am Coll Surg* 2003; 196: 32-37.
 58. Fansler RF, Taheri P, Cullinane C, Sabates B, Flint LM. Polypropylene mesh closure of the complicated abdominal wound. *Am J Surg*. 1995;170:15-8.
 59. Sharrock AE, Barker T, Yuen HM, Rickard R, Tai N. Management and closure of the open abdomen after damage control laparotomy for trauma. A systematic review and meta-analysis. *Injury*. Elsevier Ltd. 2015; 47:296-306.
 60. Atema JJ, de Vries FEE, Boermeester MA. Systematic review and meta-analysis of the repair of potentially contaminated and contaminated abdominal wall defects. *Am J Surg Elsevier Inc*. 2016;212:982-95.
 61. Caviggioli F, Klinger FM, Lisa A, Maione L, Forcellini D, Vinci V, et al. Matching biological mesh and negative pressure wound therapy in reconstructing an open abdomen defect. *Case Rep Med*. Hindawi Publishing Corporation; 2014;2014:235930.
 62. Booth JH, Garvey PB, Baumann DP, Selber JC, Nguyen AT, Clemens MW, et al. Primary fascial closure with mesh reinforcement is superior to bridged mesh repair for abdominal wall reconstruction. *J Am Coll Surg*. 2013; 217:999-1009.
 63. Holihan JL, Nguyen DH, Nguyen MT, Mo J, Kao LS, Liang MK. Mesh location in open ventral hernia repair: a systematic review and network metaanalysis. *World J Surg*. 2016;40:89-99.
 64. Majercik S, Kinikini M, White T. Enteroatmospheric fistula: from soup to nuts. *Nutr Clin Pract* 2012;27:507-12.
 65. Teixeira PGR, Inaba K, Dubose J, Salim A, Brown C, Rhee P, et al. Enterocutaneous fistula complicating trauma laparotomy: a major resource burden. *Am Surg*. 2009;75:30-2.
 66. Bradley MJ, Dubose JJ, Scalea TM, Holcomb JB, Shrestha B, Okoye O, et al. Independent predictors of enteric fistula and abdominal sepsis after damage control laparotomy: results from the prospective AAST Open Abdomen registry. *JAMA Surg*. 2013;148:947-54.
 67. Marinis A, Gkiokas G, Argyra E, Fragulidis G, Polymeneas G, Voros D. "Enteroatmospheric fistulae"-gastrointestinal openings in the open abdomen: a review and recent proposal of a surgical technique. *Scand J Surg*. 2013;102:61-8.
 68. Cheatham ML, Demetriades D, Fabian TC, Kaplan MJ, Miles WS, Schreiber MA, et al. Prospective study examining clinical outcomes associated with a negative pressure wound therapy system and Barker's vacuum packing technique. *World J Surg*. 2013;37:2018-30.
 69. Schechter WP, Ivatury RR, Rotondo MF, Hirshberg A. Open abdomen after trauma and abdominal sepsis: a strategy for management. *J Am Coll Surg*. 2006;203:390-6.
 70. Bruhin A, Ferreira F, Chariker M, Smith J, Runkel N. Systematic review and evidence based recommendations for the use of negative pressure wound therapy in the open abdomen. *Int J Surg*. 2014;12(10):1105-14.
 71. Tavusbay C, Genc H, Cin N, Kar H, Kamer E, Atahan K, et al. Use of a vacuum-assisted closure system for the management of enteroatmospheric fistulae. *Surg Today*. 2015;45(9):1102-11.
 72. Schein M, Decker GAG. Postoperative external alimentary tract fistulas. *Am J Surg*. Elsevier; 1991;161:435-438.
 73. Di Saverio S, Tarasconi A, Inaba K, Navsaria P, Coccolini F, Costa Navarro D, et al. Open abdomen with concomitant enteroatmospheric fistula: attempt to rationalize the approach to a surgical nightmare and proposal of a clinical algorithm. *J Am Coll Surg*. 2015;220:e23-33.
 74. Di Saverio S, Tarasconi A, Walczak DA, Cirocchi R, Mandrioli M, Birindelli A, et al. Classification, prevention and management of entero-atmospheric fistula: a state-of-the-art review. *Langenbeck's Arch Surg*. 2016;401:1-13.
 75. Kaushal M, Carlson GL. Management of enterocutaneous fistulas. *Clin Colon Rectal Surg*. 2004;17(2):79-88.
 76. Giner M, Laviano A, Meguid MM, Gleason JR. In 1995 a correlation between malnutrition and poor outcome in critically ill patients still exists. *Nutrition*. 1996;12:23-9.
 77. Jamshidi R, Schechter WP. Biological dressings for the management of enteric fistulas in the open abdomen: a preliminary report. *Arch Surg* 2007;142:793e796.
 78. Subramaniam MH, Liscum KR, Hirshberg A. The floating stoma: a new technique for controlling exposed fistulae in abdominal trauma. *J Trauma* 2002;53:386e388.
 79. Al-Khoury G, Kaufman D, Hirshberg A. Improved control of exposed fistula in the open abdomen. *J Am Coll Surg* 2008; 206:397e398.
 80. Di Saverio S, Villani S, Biscardi A, Giorgini E, Tugnoli G. Open abdomen with concomitant enteroatmospheric fistula: validation, refinements, and adjuncts to a novel approach. *J Trauma*. 2011;71(3):760-2.
 81. Clark CE, Walker T, Bacon L, McCoy J, Babalao O. Staged suspension of an enteroatmospheric fistula: a novel surgical approach. *Am Surg*. 2013; 79(4):E139-40.
 82. Davis KG, Johnson EK. Controversies in the care of the enterocutaneous fistula. *Surg Clin North Am* 2013;93:231-50.