International consensus conference on open abdomen in trauma

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BACKGROUND: A part of damage-control laparotomy is to leave the fascial edges and the skin open to avoid abdominal compartment syndrome and allow further explorations. This condition, known as open abdomen (OA), although effective, is associated with severe complications. Our aim was to develop evidence-based recommendations to define indications for OA, techniques for temporary abdominal closure, management of enteric fistulas, and methods of definitive wall closure.

METHODS: The literature from 1990 to 2014 was systematically screened according to PRISMA [Preferred Reporting Items for Systematic Reviews and Meta-analyses] protocol. Seventy-six articles were reviewed by a panel of experts to assign grade of recommendations (GoR) and level of evidence (LoE) using the GRADE [Grading of Recommendations Assessment, Development, and Evaluation] system, and an international consensus conference was held.

RESULTS: OA in trauma is indicated at the end of damage-control laparotomy, in the presence of visceral swelling, for a second look in vascular injuries or gross contamination, in the case of abdominal wall loss, and if medical treatment of abdominal compartment syndrome has failed (GoR B, LoE II). Negative-pressure wound therapy is the recommended temporary abdominal closure technique to drain peritoneal fluid, improve nursing, and prevent fascial retraction (GoR B, LoE I). Lack of OA closure within 8 days (GoR C, LoE II), bowel injuries, high-volume replacement, and use of polypropylene mesh over the bowel (GoR C, LoE I) are risk factors for frozen abdomen and fistula formation. Negative-pressure wound therapy allows to isolate the fistula and protect the surrounding tissues from spillage until granulation (GoR C, LoE II). Correction of fistula is performed after 6 months to 12 months. Definitive closure of OA has to be obtained early (GoR C, LoE I) with direct suture, traction devices, component separation with or without mesh. Biologic meshes are an option for wall reinforcement if bacterial contamination is present (GoR C, LoE II).

CONCLUSION: OA and negative-pressure techniques improve the care of trauma patients, but closure must be achieved early to avoid complications.

KEY WORDS: Trauma; open abdomen; negative-pressure wound therapy; enteric fistula; definitive abdominal closure.

Currently, between 10% and 15% of trauma laparotomies are managed using damage-control surgery (DCS) techniques.[1] When DCS is used, the fascial edges and the skin are purposefully left open to avoid intra-abdominal hypertension and abdominal compartment syndrome (ACS), to allow a planned reexploration, or to treat a severe intra-abdominal infection in a stepwise approach. This condition is known as open abdomen (OA). Although OA is effective, it is associated with serious complications, such as fluid and protein loss, which can produce nutritional insufficiency and a catabolic state, loss of abdominal domain from fascial retraction, and the development of huge ventral hernia if not closed early.[2,3] The most devastating and potentially life-threatening complication of OA is the development of an

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enteroatmospheric fistula (EAF), defined as the leak of gastrointestinal content into the OA field.

Since the 1980s, several strategies have been adopted for temporary abdominal closure (TAC), to allow planned abdominal reexplorations and to facilitate a definitive closure once the underlying pathology has been resolved.[4–15] Available commercial devices for negative-pressure wound therapy (NPWT)[16–18] allow good control of the abdominal domain and improve patient care and nursing. Nonetheless, all the suggested methods for TAC have several drawbacks.[19–23] While the improved knowledge of surgical strategies and technologies, nutritional support, and advances in critical care[24,25] have improved management of each phase, management of a patient with an OA can still be challenging. The aim of the first international consensus conference (ICC) on OA held in Milan in December 2014 was to develop evidence-based guidelines to correctly identify the indications for OA in trauma patients, to choose the best and most appropriate technique for TAC, to manage enteric complications, and to achieve an effective definitive closure of the abdominal wall.

PATIENTS AND METHODS

The Organizing Committee (O.C., F.C.) was established to plan the ICC on the use of OA after trauma. The international consensus was conducted according to "The Methodological Manual—How to Organize a Consensus Conference," edited by the Higher Health Institute.[26] Nine scientific societies, both Italian and international, identified by the organizing committee among those interested in the topic of OA, were asked to appoint one or two representatives each to participate the international consensus. The following societies were involved: Trauma Update Network (TUN), American Association for the Surgery of Trauma (AAST), the Italian Association of Hospital Surgeons (ACOI), the European Society of Trauma/Emergency Surgery (ESTES), the Italian Society of Anesthesia, Analgesia, Resuscitation and Intensive Care (SIAARTI), the Italian Society of Emergency Surgery and Trauma (SICUT), the World Society of Emergency Surgery (WSES), the Italian Society of Hernia and Abdominal Wall Surgery (ISHAWS), and the International Disaster Medicine Association (IDMA). The organizing committee selected a scientific board (SB, 8 members) and a national (NPE, 23 members) and an international (IPE, 4 members) panel of experts. The organizing committee and SB selected the following four topics:

1. Indications for OA in trauma patients
2. Best techniques for TAC
3. Best treatment for frozen abdomen and EAF
4. Best techniques for definitive abdominal wall closure

The national and international panelists were divided into four groups, and each was assigned a topic. A systematic review of the literature from 1990 to 2014 was undertaken by a medical reference librarian in May 2014. Two investigators (O.C., L.A.) created a preliminary search strategy by selecting the following key words: ACS/IAH, NPWT and TAC techniques, DCS, intra-abdominal sepsis, definitive abdominal closure, ventral hernia repair. Searches were conducted incorporating novel terms when relevant citations were found using the following databases: MEDLINE, PubMed, EMBASE, Scopus, and Cochrane Database of Systematic Reviews. Further literature was obtained by the manufacturers of an NPWT device (KCI, Kinetic Concepts. Inc., San Antonio, TX). Two investigators (S.C. and O.C.) independently screened titles and abstracts selecting studies according to PRISMA statements.[27] The following types of articles were included: (I) prospective randomized clinical trials, (II) observational studies in which data were collected prospectively, (III) retrospective analyses based on clearly reliable data, (IV) systematic reviews of literature, (V) meta-analyses, and (VI) relevant case series. All articles eligible for evaluation were divided according to the selected topics and sent for evaluation to members of each of the four groups. Panelists were asked to assign levels of evidence (LoE) and grades of recommendations (GoR) based on the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) hierarchy criteria (Table 1).[28] Each panel was asked to answer the key question and some specific subquestions pertaining to the assigned topic.

TABLE 1. Grading of Recommendations From Guyatt et al.[28] (GRADE)

1A. Strong recommendation, high-quality evidence	Benefits clearly outweigh risks and burdens, or vice versa	RCTs without important limitations or overwhelming evidence from observational studies	Strong recommendation, applies to most patients in most circumstances without reservation
1B. Strong recommendation, moderate-quality evidence	Benefits clearly outweigh risk and burdens, or vice versa	RCTs with important limitations (inconsistent results, methodological flaws, indirect analyses or imprecise conclusions) or exceptionally strong evidence from observational studies	Strong recommendation, applies to most patients in most circumstances without reservation
1C. Strong recommendation low-quality or very low-quality evidence	Benefits clearly outweigh risk and burdens, and vice versa	Observational studies or case series	Strong recommendation but subject to change when higher-quality evidence becomes available
2A. Weak recommendation, high-quality evidence	Benefits closely balanced with risks and burdens	RCTs without important limitations or overwhelming evidence from observational studies	Weak recommendation, best action may differ depending on the patient, treatment circumstances, or social values
2B. Weak recommendation, moderate-quality evidence	Benefits closely balanced with risks and burdens	RCTs with important limitations (inconsistent results, methodological flaw, indirect or imprecise) or exceptionally strong evidence from observational studies	Weak recommendation, but action may differ depending on the patient, treatment circumstances, or social values
2C. Weak recommendation, low-quality or very low-quality evidence	Uncertainty in the estimates of benefits, risks, and burdens; benefits, risks, and burdens may be closely balanced	Observational studies or case series	Very weak recommendation, alternative treatments may be equally reasonable and merit consideration.

RCT, randomized-controlled trial.

On December 14, 2014, a meeting was held involving the organizing committee, IPE, SB, and the representatives of the scientific societies to discuss topics and define statements to be presented during the conference. On December 15, 2014, the ICC took place in Milan with 250 delegates. For each topic, a 2-hour session was held with a clinical case presentation, a literature review by a member of the NPE, a lecture by a member of the IPE, and a discussion with the audience. It was recorded for later analysis and subsequent manuscript preparation.

RESULTS AND DISCUSSION

The database searches identified 276 citations (Fig. 1). After removing duplicates, titles not related to the topic, case reports, articles on nontrauma patients and articles where no full text was available, 126 citations were excluded. Among the remaining 150 articles, 74 were excluded because of overlapping data and because they were letters to the editor. The resulting 76 articles were divided according to each topic: 6 for Topic 1, 25 for Topic 2, 24 for Topic 3, and 21 for Topic 4. These studies were included and evaluated for GoR and LoE by the NPE and the IPE. Statements about each topic were suggested by the SB, approved by the IPE and the scientific societies, and discussed with the audience during the Milan conference.

1. Indications for OA in Trauma Patients

Questions

A. Is empiric use of OA indicated in patients with risk factors for ACS?
B. When is surgical abdominal decompression formally required in ACS?
C. What conditions, other than ACS, require OA in trauma?

Statements

A. Empiric use of OA in trauma patients with risk factors for ACS is indicated:
   in the case of DCS for bleeding injuries requiring packing and planned reoperation within a day or two [GoR B, LoE II]
   in the presence of extreme visceral or retroperitoneal swelling or elevated bladder pressure; after surgery when abdominal closure is attempted [GoR B, LoE II]

B. Decompressive laparotomy is indicated in ACS if medical treatment has failed [GoR B, LoE II]
C. Other conditions that require OA in trauma are as follows:
   in the presence vascular/gastrointestinal injuries, mesenteric ischemia, or hematoma, necessitating a second look [GoR B, LoE II]
   if gross peritoneal contamination not amenable to resolution at the first operation is present [GoR C, LoE II]
   in the case of major abdominal wall tissue loss [GoR B, LoE II]
   when the patient's fascia is in poor condition [GoR C, LoE II]

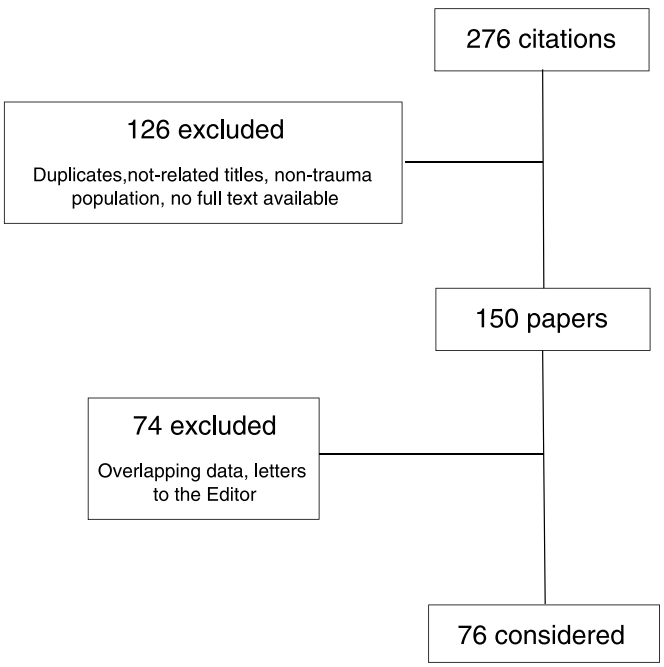

Figure 1. Bibliography search (PRISMA).

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OA may be defined as leaving the abdominal fascial edges open.[29] As part of DCS, it represents a temporizing measure to rapidly terminate the initial operation, facilitating abbreviated care in physiologically depleted patients, once the control of hemorrhage and contamination has been achieved. Severely traumatized patients are at risk of developing ACS or multicompartment syndrome[30,31] because of visceral or retroperitoneal swelling, recurrent bleeding, and intraperitoneal packing.[32,33] This situation is most likely to occur if the patient experiences physiologic exhaustion as suggested by pH lower than 7.2, core temperature lower than 34°C, estimated blood loss greater than 4 L, transfusion requirement of more than 10 U of packed red blood cells, systolic blood pressure less than 70 mm Hg, lactate levels greater than 5 mmol/L, base deficit (BD) greater than −6 in patients older than 55 years or greater than −15 in patients younger than 55 years, and/or prothrombin time greater than 1.6.[31] In trauma patients undergoing laparotomy, these are all associated with increased morbidity and mortality and should prompt the surgeon to perform an abbreviated procedure, leaving the abdomen open. For this reason, the two major indications for the use of the OA in trauma are the prevention of abdominal ACS or its treatment if medical strategies have failed[31] and DCS for intra-abdominal life-threatening bleeding.

Other indication for an OA is the need of a second look in abdominal vascular injuries and management of intra-abdominal sepsis.[32] In the case of severe intra-abdominal infection, the surgeon may select OA when an intraperitoneal septic focus is not completely controlled at the time of the first operation. The loss of abdominal wall after trauma is usually associated with extensive contamination and mandates OA. Lastly, some experts use OA as treatment for refractory intracranial hypertension associated with multicompartment syndrome, but neither high grades of recommendation nor high levels of evidence are available in the literature regarding this. Further studies are required on the effects of abdominal hypertension and decompression in severe traumatic brain injury.

Table 2 summarizes referral articles for Topic 1.

2. Best Techniques for TAC

Questions

A. When is NPWT indicated in OA?
B. Which device is recommended for NPWT?
C. What negative-pressure level is best in patients after large-volume bleeding?

TABLE 2. Reviewed Articles for Topic 1

Reference	Year	Design	Comments	GoR-LoE
Bograd et al.[29]	2013	Prospective military	Indications for OA: DC in more compromised patients	2C
DuBose et al.[30]	2013	Prospective multicenter	Indications for OA: DC (70%); early decompression (26%); decompression (0.3%)	2B
Diaz et al.[32]	2010	Systematic review	Indications for OA: aggressive fluid resuscitation, pH < 7.3, core temperature < 35°C, massive transfusion, ACS	2B
Open Abdomen Advisory Panel [3]	2009	Systematic review	Indications for OA: DC, reexploration; prevention of ACS; decompression	2B
Regner et al.[31]	2012	Systematic review	Indications for OA: pH < 7.2, temperature 34°C, estimated blood loss > 4 L; transfusion > 10 U of packed red blood cells, SBP < 70 mm Hg; BD > −6 in patients < 55 y or BD > −15 in patients > 55 y of age, lactate levels > 5 mmol/L, PT > 16, or PTT > 50	2C
Teixeira et al.[33]	2008	Prospective	Indications for OA: DC, massive transfusion	2C

DC, damage control; PT, prothrombin time; PTT, partial thromboplastin time; SBP, systolic blood pressure.

D. What is the role of NPWT in systemic inflammatory response after abdominal trauma?
E. Is abdominal instillation an option to be considered in OA?
F. Are anastomoses safe in OA?

Statements

A. NPWT in OA drains peritoneal fluids, improves nursing care, and prevents retraction of fascial edges, which facilitates wall closure. Fascial traction systems may be helpful [GoR B, LoE I].
B. Commercially available devices for NPWT have been recommended since 2011 [GoR B, LoE I].
C. If coagulopathy is present, the suggested pressure of NPWT devices in OA for trauma starts from −75 mm Hg, during the first 48 hours to avoid the risk of hemorrhage [GoR B, LoE II].
D. NPWT reduces levels of endotoxin and inflammatory molecules (IL-6, IL-10, TNF-α, TNF-β, and C-reactive protein) in the peritoneal fluid [GoR B, LoE I].
E. Instillation associated with NPWT should be considered because it prevents bowel loops adhesions and dehydration, facilitating exploration and definitive closure [GoR B, LoE II].
F. OA and NPWT do not harm intestinal anastomoses as long as these are buried deeply in the abdominal cavity [GoR A, LoE II].

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The abdominal wall is best closed after the visceral edema subsides and before the peritoneal space between the viscera and the abdominal wall becomes covered with granulation tissue, which causes adhesion of the abdominal content to the undersurface of the abdominal wall, precluding definitive abdominal wall closure. Lateral retraction of the fascial edges results in a progressively larger gap. The ideal method for TAC should prevent loss of domain, limit contamination, allow egress of peritoneal fluid, and avoid adhesion formation. It should also be cost-effective. Options can be divided into skin approximation techniques (towel clip closure, the Bogota bag, the silo technique);[34,35] fascial closure techniques (FCTs), using an interposition graft material sutured to the abdominal fascia (e.g., the Wittmann Patch);[36] or NPWT (Barker's vacuum pack, V.A.C. Abdominal Dressing System, ABThera).[18,37–43]

Skin techniques have been abandoned because of high complication rates. Both the Bogota bag and the silo technique are prone to fluid leakage and evisceration. They do not prevent wall retraction, and they do not allow effective egress of peritoneal fluid. Moreover, the artificial material limits the expansion of the abdominal content to a fixed volume, with subsequent risk of ACS development, despite use of OA, as well as fistula formation.[31] Skin closure using towel clips is only used intraoperatively during DCS for short closure after initial packing to allow restoration of physiologic parameters.

The FCTs with nonabsorbable meshes provide a mechanism to limit the loss of domain due to fascial edge retraction, but they do not prevent adhesions between viscera and the abdominal wall, while increasing the risk of fascial and bowel trauma. Moreover, these techniques do not allow the evacuation of peritoneal fluid. Interposed absorbable meshes are mostly used in planned ventral hernia to form a bed of granulation tissue for future skin grafting. The most significant drawbacks of FCTs are the low rate of primary closure with absorbable mesh and the high rate of fistula formation with nonabsorbable graft.[2,3]

The available NPWTs all use the same technique with various refinements: a plastic interface protects the bowel, prevents adhesions, and as it is perforated, allows fluid egress. A macroporous material (gauze in Barker's technique, Granu Foam sponge in commercial devices) is then applied over the plastic layer and is in contact with the fascia and subcutaneous tissue. This sponge is then covered with an adhesive occlusive dressing, and a suction drainage system is applied to the superficial layer for the aspiration of peritoneal fluid. The optimal therapeutic amount of negative pressure that maximizes tissue growth is approximately −125 mm Hg, with some flexibility based on clinical conditions and time of management. If active bleeding caused by coagulopathy is suspected, the pressure level should be lower, approximately −75 mm Hg.[3] In severely traumatized patients, an exaggerated systemic inflammatory response occurs because of activation of proinflammatory cytokines, mostly into the peritoneal cavity. This phenomenon is probably related to microcirculatory disruption induced by hemorrhagic shock, which may lead to loss of intestinal barrier function, bowel edema, and formation of proinflammatory-mediator–rich ascites. Negative-pressure devices that allow peritoneal fluid egress may reduce local cytokine levels.[39] The use of instillation with NPWT seems to improve bowel loop moisture, preventing adhesions and improving abdominal closure rates.[41] To reduce the risk of fistula formation in the presence of an intestinal anastomosis while applying NPWT, the surgeon must ensure that the anastomotic site is technically sound. It should be buried deeply within the pelvis or central abdomen under multiple loops of bowel or out laterally under the abdominal wall.[18]

Despite the different distribution patterns of the preset negative pressure, NPWT is still the best option to manage

OA. Commercial devices are associated with improved nursing care because of computer-controlled negative pressure that warns of system leaks. Generally, these techniques require dressing changes every 48 hours.

Table 3 summarizes the reviewed articles for Topic 2.

3. Treatment of Frozen Abdomen With or Without Fistula

Questions

A. What are the risk factors for a frozen OA?
B. What are the risk factors for fistula formation in OA?
C. What is the role of nutritional/metabolic support in patients with OA and fistula (enteral nutrition [EN]/parenteral nutrition, caloric intake, site of enteral administration, immunonutrition)?
D. What is the role of NPWT in the management and nursing care of OA with fistula?
E. What is the best surgical management for fistula control and definitive correction?

Statements

A. Risk factors for frozen abdomen in OA involve lack of wall closure within 8 days and nonuse of plastic sheets over bowel loops [GoR C, LoE II].

TABLE 3. Reviewed Articles for Topic 2

Reference	Year	Design	Comments	GoR-LoE
Barker et al.[4]	2007	Retrospective	VAC is safe, ease to use, and cost-effective.	2C
Bee et al.[19]	2008	RCT	VAC is useful and safe to use.	2B
Bovill et al.[14]	2008	Systematic review	Commercial devices are the best option; negative pressure −25/−50 mm Hg if coagulopathy is present.	2C
Campbell et al.[2]	2010	Prospective	Modified VAC-assisted closure is the best option for an early abdominal wall closure.	2C
Carlson et al.[5]	2013	Prospective observational	NPWT is associated with a reduction in delayed primary fascial closure.	2C
Cheatham et al.[6]	2013	Prospective observational open-label	NPWT is associated with an increased rate of primary fascial closure.	2C
Cipolla et al.[34]	2005	Retrospective	NPWT is indicated if there is gross contamination, bowel edema, risk of bleeding, and need of a second look.	2C
Demetriades and Salim[1]	2014	Systematic review	Commercial devices of NPWT are indicated. In cases of bowel edema, to allow fluid drainage and to prevent wall retraction; negative pressure at −25/−50 mm Hg if coagulopathy is suspected.	2C
Fluieraru et al.[20]	2013	Retrospective case-series	NPWT with instillation improves tissue granulation, without complications.	2C
Frazee et al.[15]	2013	Retrospective	Commercially available NPWT devices had a significantly greater success than Barker's technique.	2C
Hutan et al.[21]	2013	Retrospective	Reduced mortality and increased wall closure rate with VAC; increased fistula diversion.	1C
Keramati et al.[36]	2008	Retrospective	The Wittmann patch allows early primary fascial closure without complications, prevents bowel dessication, minimizes wall tissue damage, prevents contamination, and controls fluid egress.	1C
Miller et al.[38]	2004	Prospective	NPWT is indicated after DCS.	2C
Navsaria et al.[17]	2013	Prospective	NPWT is safe and effective.	1C
Navsaria et al.[37]	2003	Retrospective	NPWT is safe in case of ACS, if abdominal wall defects are present.	2C
Olona et al.[18]	2015	Retrospective comparative study	ABThera can achieve faster closure after DCS, ACS, severe posttraumatic sepsis.	1B
Quyn et al.[22]	2012	Systematic review	Wittmann patch and VAC offer the best outcome in the absence of sepsis; when sepsis is present, VAC had the highest delayed primary fascial closure but the lowest mortality rate.	2A
Rao et al.[23]	2007	Retrospective	High fistula rate with VAC	2A
Roberts et al.[39]	2013	RCT-single center	ABThera permits reduction of systemic extent of inflammatory response during OA.	1B
Roberts et al.[40]	2012	Systematic review	NPWT improves survival compared with other techniques	2B
Rycerz et al.[41]	2013	Review	NPWT with instillation induced 43% more granulation tissue compared with normal NPWT	2B
Rycerz et al.[43]	2013	Review	Periodic instillation facilitates more uniform exposure throughout the wound	2B
Sherck et al.[42]	1998	Retrospective	Barker's vacuum technique represents a physiologic milieu for the abdominal viscera, facilitates nursing, and promotes late closure.	2C
Subramonia[16]	2009	Prospective	V.A.C. therapy is useful in the management of OA.	1B
Tremblay et al.[35]	2001	Retrospective	Silo technique may allow early abdominal closure	2C

RCT, randomized-controlled trial.

B. Risk factors for fistula formation in OA are as follows:
the presence of bowel injury and repairs or anastomosis [GoR C, LoE I];
colon resection during DCS [GoR C, LoE I];
the large fluid resuscitation volume (>10 L/48 hours) [GoR C, LoE I];
the presence of intra-abdominal sepsis/abscess [GoR C, LoE I];
the number of reexplorations and delayed abdominal closure [GoR C, LoE I];
the use of polypropylene mesh directly over the bowel [GoR C, LoE I].

C. EN with standard polymeric formula is beneficial and safe and should be started as soon as possible [GoR C, LoE I]
Suggested caloric daily intake is approximately 20 to 30 nonprotein kcal/kg, and 1.5-g/kg to 2.5-g/kg proteins [GoR C, LoE I].
Nitrogen balance has to be corrected with the addition of 2-g/L protein per liter of fistula output [GoR C, LoE II].
Trace elements, glutamine, ώ3-fatty acids have to be eventually added to EN [GoR C, LoE II].
Fistuloclysis is an alternative if the gastric/jejunal route is unavailable in proximal fistulas[GoR C, LoE II].

D. In the presence of fistulas in OA, NPWT makes it possible to isolate the fistula, protecting the surrounding tissues from enteric spillage [GoR C, LoE II].
Different techniques and devices (nipple, fistula ring, floating stoma) can be applied to control fistula effluent [GoR C, LoE II].
Direct intubation of fistulas is not recommended [GoR C, LoE II].

E. The best surgical strategy to manage fistula output is the transformation of EAF into a standard enterostomy [GoR C, LoE II]. The definitive correction of a fistula is surgical resection after 6 months to 12 months, if it is still open [GoR C, LoE II].

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The OA acts as a catabolic drain. The large open surface area results in fluid and protein loss, while the healing process consumes calories and proteins. Unprotected bowel is prone to dessication, iatrogenic trauma, and fistula formation. The complication rate of OA is higher the longer the period between OA and definitive fascial closure.[44] Lateral fixation of the bowel prevents midline fascia closure with chronic exposure of abdominal contents to the atmosphere. Formation of an EAF is one of the more dreaded complications because of local inflammation, sepsis, and metabolic imbalance.[45–48] In OA when the fascia cannot be closed early, the incidence of fistulas is approximately 15%.[49] Large bowel resection, large-volume resuscitation, and repeated manipulations of edematous and friable bowel are independent risk factors for fistula formation.[46] For this reason, every effort should be made to close the fascia within 8 days.[49]

The key components of management of the patient with an EAF include sepsis control, nutritional support, and local wound care.[50–55] Nutritional support should be via enteral feeding (EN) whenever possible. It should be started as soon as possible to prevent malnutrition. The only contraindication to EN is a usable bowel shorter than 75 cm.[53] A standard polymeric formula supplying a daily intake of 20-kcal/kg to 30-kcal/kg nonprotein calories with 1.5-g/kg to 2.5-g/kg proteins is used to obtain a positive nitrogen balance. A high-output fistula is likely to require 1.5 to 2 times the usual calories because of ongoing losses. Enhanced formulas containing glutamine and 3-fatty acids may be helpful for the anti-inflammatory effects.[54] If the proximal enteral route is not available, fistuloclysis may help to assist with maintenance of fluid and electrolyte balance.[54]

Small-sized fistulae may be sealed with primary suture and cyanoacrylate or biologic dressing (i.e., human dermal matrix or cadaveric skin graft) kept in place by fibrin glue. In high-output fistula, the maintenance of skin integrity is of the utmost importance, to prevent the painful and progressive erosion of surrounding tissues. Local wound care can be attempted with NPWT applied over granulation tissue around the fistula, to control the fistula effluent. The fistula output may be controlled with a baby bottle nipple applied over the fistula opening with a layer of colostomy paste to seal. A Malecot or Foley catheter can be placed through a hole on the nipple tip, and an NPWT is placed over the exposed viscera around to promote granulation. The Foley catheter may be advanced and inflated into the fistula opening to improve diversion in large, high-output fistula. Another popular method of fistula control is the floating stoma: a colostomy bag is applied over a plastic silo with an opening sutured to the margins of leaking bowel. Recently, the VAC chimney technique has been described. A chimney is created with a white sponge dressing, and a plastic tube is placed inside the chimney. A conventional VAC is then applied to cover the OA with the negative-pressure connector directly placed over the chimney.[56]

Skin grafting around the fistula over the granulating abdominal wound may be helpful to apply a colostomy bag for temporary control of output, to allow time for the inflammation to subside and the adhesions to mature, until surgical takedown.[57] The definitive treatment of fistulas should be performed when the patient is fully recovered and in good nutritional status, usually 6 months to 12 months later. The ability to pinch the skin graft up off the underlying viscera confirms the resolution of adhesions between the skin and peritoneal content. Before the reconstruction of bowel integrity is attempted, it is mandatory to have a clear understanding of the anatomy of fistulas, delineating as clearly as possible the intestinal segment involved in the fistulation and identifying the proximal and distal gastrointestinal tract through contrast studies, to exclude any stricture distal to the fistulas. Careful entry into the neoperitoneal cavity is made through the intact abdominal wall with a surgical incision that has to be individualized either at the margin of the wound or laterally, away from EAF edges.[58]

Table 4 shows the reviewed articles for Topic 3.

4. Techniques of Definitive Closure of Abdominal Wall After OA

Questions

A. When can OA be definitely closed, and what techniques can be applied?
B. When does a planned ventral hernia need to be considered?
C. Is a biologic mesh a reliable option for closure of OA?
D. Which biologic mesh is recommended between cross-linked and non–cross-linked types?
E. What is the long-term outcome of using a biologic mesh?

Statements

A. Definitive closure of the abdominal wall has to be obtained as soon as possible [GoR C, LoE I]. Different techniques can be applied for different settings:
direct closure with dynamic traction techniques in early closure with little fascial gap [GoR C, LoE I]
component separation if abdominal wall gap is less than 20 cm and in the presence of a Type I defect (unharmed skin) [GoR C, LoE I]

TABLE 4. Reviewed Articles for Topic 3

References	Year	Design	Comments	GoR-LoE
Al-Khoury et al.[24]	2008	Prospective case-series	Allows control of proximal fistula effluent; the use of suction dressing peri-EAF minimizes contamination.	2C
Becker et al.[25]	2007	Review	NPWT has a role in the isolation of the fistula and the enteric content diversion with gravity or suction drainage, allowing wound granulation around.	2C
Bradley et al.[46]	2013	Prospective multicenter	The following are risk factors for the fistula formation in OA: bowel injury and repair or anastomosis, large fluid resuscitation volume (>10 L/48 h), intra-abdominal sepsis/abscess , number of reexplorations and timing of delayed abdominal closure (>8°d).	1C
Burlew et al.[47]	2011	Retrospective	Delayed abdominal closure increases the risk of fistula formation	2C
Burlew et al.[51]	2012	Retrospective	EN has to be started as soon as possible (<36 h)	2C
Byrnes et al.[52]	2010	Retrospective	EN reduces bacterial translocation, pulmonary infection rate, and abscess formation; it allows early fascial closure -Suggested caloric intake: 20–30 kcal/kg/d 1.5-g/kg to 2.5-g/kg protein If EAF are present, caloric intake increases 1.5-fold to 2-fold; nitrogen balance: 2 g of nitrogen per liter of fistula output	1C
Davies and Johnson[48]	2013	Systematic review	Little evidence about risk factors for frozen OA	2C
Diaz et al.[45]	2011	Systematic review	Creating a floating stoma is a useful technique for the management of fistulae	2C
DuBose and Lundy[49]	2013	Prospective observational multicenter study	Fistula prevention in OA requires the following actions: coverage of hollow viscera with omentum or another protective nonadherent barriers, OA performed by either experienced professionals or surgeons with specific training, achieving closure as early as possible to minimization of manipulation	2C
Friese[50]	2012	Systematic review	Direct intubation of the fistula direct intubation.	2C
Goverman et al.[59]	2006	Prospective case-series	Fistula management with NPWT can be obtained using different techniques: nipple, fistula ring, floating stoma	2C
Jamshidi and Schecter[60]	2007	Retrospective	In the management of OA with fistula, NPWT has a role in the isolation of the fistula and the enteric content diversion with gravity or suction drainage, allowing wound granulation around.	2C
Lambe et al.[61]	2012	Retrospective	The subtotal pedicled thigh flap is a safe and effective method in providing definitive treatment for patients with massive EAF	2C
Latifi et al.[58]	2012	Retrospective	Careful planning and advanced surgical techniques are required, often involving the use (alone or combined) of biologic mesh and composite tissue transfer	2C
Layton et al.[57]	2010	Prospective case-series	NPWT allows granulation around EAF, with formation of floating stoma	2C
Majercik et al.[53]	2012	Systematic review	Absolute contraindications to EN are intestinal discontinuity or intestinal length < 75 cm; EN with standard polymeric formula; if short bowel is present, use elementary formula; if high-output EAF is present, add trace elements and vitamin C; immunonutrition reduces ventilatory days and infection-related morbidity; proton pump inhibitors, somatostatin and octreotide may reduce fistula output; fistuloclysis has to be considered if gastric/jejunal routes are not available.	2C
Polk and Schwab[54]	2012	Systematic review	Aggressive nutritional therapy is necessary to reverse the catabolic state in patients.	2C
Ramsay and Mejia[62]	2010	Retrospective case-series	Management strategies of fistulas in the OA have included the use of skin grafts around the fistula and conversion of the fistula to a controlled ostomy, resection of the fistula and primary anastomosis, use of tissue flaps to cover the fistula, fistula diversion using drains, use of vacuum-assisted wound care, use of fibrin products, and octreotide.	2C
Redden et al.[44]	2013	Retrospective	While prevention is the best treatment for EAF, a thought out and committed approach to patient management will help ensure the best possible outcome	2C
Schecter[63]	2006	Systematic review	Intubation of a fistula in the middle of an OA is a grave error. It not only fails to control the drainage but also always results in a larger hole.	2C
Di Saverio et al.[56]	2015	Systematic review	Proposal of an algorithm for decision making in the treatment of EAF.	2C
Stremitzer et al.[64]	2011	Retrospective	Fistulas that do not resolve spontaneously should be considered for surgical resection between 6 mo and 12 mo	2C
Wang et al.[65]	2013	Prospective case-series	Fistula patch allows control of enteric spillage, permits EN application, and facilitates nursing.	2C
Yuan et al.[55]	2011	Retrospective	Early EN may be successfully obtained	2C

flaps if wall defects are more than 20 cm in the absence of skin (Type II defect) [GoR C, LoE I]

rotational flaps for medium-sized defects within the arc of rotation [GoR C, LoE I] and microvascular free flaps for large defects away from the site of donation [GoR C, LoE I]

B. A planned ventral hernia has to be considered if
severe and persistent contamination of the peritoneal cavity is present [GoR C, LoE II]

EAF has been present for a long time [GoR C, LoE II]

the patient has been critically ill for a long time [GoR C, LoE II]

C. A biologic mesh is a reliable option for definitive abdominal wall reconstruction if
a large wall defect is present [GoR C, LoE I]

bacterial contamination, comorbidities, and difficult wound healing exist [GoR C, LoE I]

if a biologic mesh is used to reconstruct the abdominal wall, NPWT can be used to facilitate granulation and skin closure [GoR C, LoE I]

D. Non–cross-linked biologic meshes seem to be preferred in sublay position when the linea alba can be reconstructed [GoR C, LoE II].

Non–cross-linked biologic mesh is easily integrated, with reduced fibrotic reaction [GoR C, LoE II] and lesser infection and removal rate [GoR C, LoE II].

E. The long-term outcome of a bridging non–cross-linked biologic mesh is laxity of the abdominal wall and a high rate of recurrent ventral hernia [GoR C, LoE II].

In the bridge position (no linea alba closure), cross-linked biologic meshes are associated with less ventral hernia recurrence [GoR C, LoE II].

Scientific Foundation

Definitive wall reconstruction may be obtained earlier or later. Early closure is easily achieved before the appearance of granulation tissue with simple suturing of fascial edges or by applying wall traction techniques.[66,67] Late abdominal wall reconstruction may represent a formidable technical challenge, where a planned ventral hernia is justifiable only when the patient's condition does not allow any earlier definitive closure.[66]

Direct closure should be achieved without tension, and this is usually possible when the fascial edges are approximately 3 cm to 7 cm apart. When this cannot be achieved, different surgical techniques must be considered. Component separation can be used to bring fascia edges closer to each other, allowing primary closure,[68–75] provided that the fascia is well perfused and clean. The easiest approach is through the anterior component separation,[71] by dissecting the external oblique muscle from the internal oblique muscle in an avascular plane. The external oblique muscle is divided vertically on both sides from just below the costal margin to just above the inguinal ligament. In this way the flap of the rectus muscle can be advanced by 10 cm around the midline. If the midline fascia does not reapproximate, posterior component separation (retrorectus dissection) allows for a greater medialization of the rectus muscle. To perform the posterior component separation, an incision is made in the posterior rectus sheath, spanning the entire length of the muscle. Preserving neurovascular structures on the posterior aspect of the muscle is crucial.[71] Component separation should be performed simultaneously with fascial closure at the end of OA treatment. A system that combines vacuum and mesh-mediated fascia traction has been proposed in a prospective study including 151 OA patients with a median OA time of 14 days, providing a 76.6% rate of fascia closure.[7] In a recent review and meta-analysis in OA in nontrauma patients, NPWT with continuous fascial traction showed the best results in terms of achieving delayed fascial closure.[72]

Reinforcement of the component separation can be obtained using meshes in weak abdominal wall. These can be placed in an underlay position (within the peritoneal cavity) or as a sublay (within the retrorectus space). If the operating field is not contaminated, polypropylene meshes can be used in the sublay position. If the mesh is in the underlay position, the use of a composite mesh seems wise. After few days of OA, the field has to be considered contaminated, and the best option is a biologic mesh, although its progressive reabsorption likely leads to long-term laxity or incisional hernia.[68] A reinforcement with sublay non–cross-linked biologic mesh is the preferred choice when the midline is able to be reconstructed. The biocompatible characteristics of non–cross-linked scaffolds facilitate tissue ingrowth and remodeling, while minimizing the risk of encapsulation and fibrotic tissue formation. In addition, non–cross-linked mesh does not stretch, thus allowing for precise evaluation of tension intraoperatively. This sublay technique results in a stronger repair and a lower risk of hernia recurrence. The association with a component separation allows for mesh coverage, thereby reducing the risk of infection. In some cases, despite having performed component separation, a fascial gap may persist. In this situation, a cross-linked biologic mesh should be used to close the gap. Cross-linked meshes are a valuable option for bridging because of their long-term resistance, due to their ability to prevent collagenase destruction.[73] Seroma and infection should be avoided by draining subcutaneous space. NPWT can be used on top of mesh if exposed,[74] promoting a granulation tissue layer, which allows the application of a skin graft.

A planned ventral hernia is unavoidable in critically ill patients with long-term OA for abdominal infection and/or EAF. Granulation over bowel loops may be encouraged using synthetic absorbable mesh. Split-thickness skin graft represents the only way to cover granulation tissue over bowel loops. These patients, 6 months to 12 months after complete resolution of the acute situation and after a full recovery, can undergo abdominal wall reconstruction with component separation techniques with or without meshes. The use of component separation for large defects may create excessive tension with the risk of causing tissue necrosis and ACS. A major concern when repairing these large abdominal wall defects is the presence (Type I defects) or lack (Type II defects) of intact skin to cover the hernia defect and which therefore require different surgical strategies.[76–80] In Type II defects, vascularized flaps, pedicled flaps for small- and mid-sized defects within the flap's rotational arc, or free flaps such as tensor fasciae latae for extensive thoracoabdominal defects can be used. These flaps provide safe autologous tissue coverage, permitting a single-stage reconstructive solution. For these complex reconstructive interventions, a multidisciplinary approach with a general and a plastic surgeon is advised (Table 5).

CONCLUSION

The use of the OA represents an important improvement in the care of severely injured trauma patients. Its benefits include facilitating an abbreviated laparotomy, using damage

TABLE 5. Reviewed Articles for Topic 4

References	Year	Design	Comments	GoR-LoE
Acosta et al.[7]	2011	Prospective	Vacuum-assisted and mesh-mediated fascial closure methods provide high rate of closure after long-term OA	2C
Bjarnason et al.[8]	2013	Prospective multicenter	Incisional hernia incidence after VAWCM is high	1C
de Moya et al.[68]	2008	Prospective	HADM is an alternative for unclosable abdomen with no fistula formation	2C
Dennis et al.[67]	2013	Prospective	TAWT consistently recaptures lost domain, preserves the leading fascial edge, and eliminates the need for biologic bridges, components separation, or skin grafting	2C
DiCocco et al.[69]	2010	Retrospective	Modified component separation is the procedure of choice for giant wall defects.	1C
Dietz et al.[10]	2012	Prospective	Modified component separation is indicated for giant wall defect.	1C
Drumond[9]	2010	Prospective	Planned ventral hernia in critically ill patient is an acceptable option.	2C
Gutarra et al.[79]	2009	Prospective	Bipedicle myofascial oblique rectus flap is a low-cost procedure to close giant wall defects.	2C
Haddock et al.[70]	2013	Retrospective	ABRA system resulted in an 83% fascial apposition rate	2C
Kääriäinen and Kuokkanen[75]	2013	Review	Biologic mesh support tissue regeneration. The disadvantage of the biologic mesh may be some laxity or bulging observed over time. Component separation is an option for late wall reconstruction	2C
Kreis et al.[66]	2013	Review	Planned ventral hernia can be performed if loss of domain is present in critically ill patients	2C
Kushimoto et al.[78]	2007	Retrospective	An anterior rectus abdominis sheath turnover flap may reduce the need for skin grafting and subsequent abdominal wall reconstruction	2C
Leppäniemi[12]	2009	Review	Component separation is useful in Type I defects; use free flaps for defects > 40 cm^2; rotational flaps to cover medium-sized defect in arch of rotation and free flap to cover defects away from donation site	2C
Pauli and Rosen[71]	2013	Review	Posterior component separation with sublay mesh is appropriate to repair ventral hernia	2C
Pomahac and Aflaki[13]	2010	Retrospective	NCPDS seems to be a safe and effective alternative to prosthetic mesh in the reconstruction of complicated abdominal wall defects.	2C
Poulakidas and Kowal-Vern[73]	2009	Retrospective	Component separation allows early closure in burned patients	2C
Rasilainen et al.[74]	2012	Retrospective	Hernias that develops in the long laparostomy wound are often giant and significantly worsen quality of life	2C
Scott et al.[11] b	2006	Retrospective	The tensile strength, suture pull out force, and long-term durability makes HADM the ideal bioprosthetic material for the OA	2C
Scott et al.[80]	2005	Review	Biologic prostheses can be used in large wall defect VAC	2C
Tukiainen and Leppäniemi[76]	2011	Retrospective	Vascularized flaps provide healthy autologous tissue coverage without implantation of foreign material at the closure site. Pedicled flaps can be used in small and mid-sized defects within the arch of rotation of the flap. In contrast, extensive upper midline abdominal wall and thoracoabdominal defects usually require a free flap	1C
Vertrees et al.[77]	2008	Retrospective	Use of biologic mesh as either final EDAC closure or with vacuum-assisted closure also requires Long-term follow-up to justify its increased cost and increased risk of abdominal wall laxity.	2C

ABRA, Abdominal Reapproximation Anchor; EDAC, early definitive abdominal closure; HADM, human acellular dermal matrix; NCPDS, non-cross-linked porcine dermal scaffold; TAWT, transabdominal wall traction; VAWCM, vacuum-assisted wound closure method.

control in a physiologically depleted patient as well as preventing the onset of ACS in aggressively resuscitated patients. The OA can be managed with several techniques for TAC. Application of NPWT prevents loss of the abdominal domain, thus avoiding fascial edge retraction and facilitating patient care. The drawbacks of an OA include high metabolic requirements, the risk of EAF formation, and the difficulties in achieving a primary abdominal wall closure once too much time has elapsed. Metabolic support, control of causes of sepsis, and individualized wound care in the presence of fistulation are the mainstays of OA management. Definitive closure must be attempted only in patients who have completely recovered, through the application of different surgical strategies, depending on the duration of OA treatment and the size of the residual wall defect.

AUTHORSHIP

O.C., S.C., T.S., S.H., A.L., and W.B. organized and designed the consensus, decided the final statements, and wrote and edited the study. F. Ca., L.A., A.C., E.D., G.Ga., G.G.o., G.Na., P.P., F.G., P.D.R., G.No., G.T., and S.Ri. proposed the statements for various topics. S.M., S.Rau., S. Raz., A.M., F.M., S.D.S., M.C., F.Co., J.N., C.C., F.Me., F.Mo., M.B., M. L., A.V., L.F., M.Z., P.D.R., F.S., R.M., and E.C. revised the literature.

DISCLOSURE

The authors declare no conflicts of interest.

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