Journal of Pediatric Surgery Case Reports 58 (2020) 101471

Contents lists available at ScienceDirect

Journal of Pediatric Surgery Case Reports

journal homepage: http://www.elsevier.com/locate/epsc

Bogotà bag for pediatric Open Abdomen

Vito Briganti [a], Stefano Tursini [a,*], Caterina Gulia [b], Giovanni Ruggeri [c], Tommaso Gargano [c], Mario Lima [c]

[a] Operative Unit of Pediatric Surgery - Azienda Ospedaliera San Camillo Forlanini, Roma, Italy
[b] Operative Unit of Urology – Ospedale Della Misericordia, Grosseto, Italy
[c] Operative Unit of Pediatric Surgery – AOU "S.Orsola – Malpighi" Hospital – University of Bologna, Bologna, Italy

ARTICLE INFO

Keywords:
Bogotà bag
Pediatric
Open abdomen
Complex abdomen
Abdominal compartment syndrome

ABSTRACT

The management of a "Complex Abdomen" (CA) and the choice of the best way or technique to deal with it is still a challenge for surgeons. When there are the criteria to define an abdomen as a complex one, whether in emergency or elective surgery, the abdomen may need to remain open to allow access for re-operation and time for decompression. The use of an "Open Abdomen" (OA) as a surgical option permits an easy re-exploration, the control of the abdominal contents, the reduction of the risk of intra-abdominal hypertension (IAH) and consequent Abdominal Compartment Syndrome (ACS) and the preservation of the fascia for closure of the abdominal wall [1–4]. Many different techniques have been described to manage the OA and the Temporary Abdominal Closure (TAC) [5–7]. This kind of approach to the CA, well known by pediatric surgeons and widely used in the management of large gastroschisis, is now used also in other situations. We describe our experience with the Bogotà bag in one young man and three children affected by different pathologies, in the first and third one the OA was necessary because of a massive peritonitis due to acute appendicitis while in the last two cases a congenital digestive malformation was present at birth. The Bogotà bag technique is safe, easily managed and less expensive than other techniques and can be safely used in children and young adults.

1. Introduction

The term CA is used to describe a clinical condition in which there is a high risk of compartment syndrome, suture dehiscence and/or early re-do laparotomy/second look [2,8,9]. These situations are related to patient, disease and surgical risk factors and may often occur in emergency surgery for critical patient, trauma, abdominal sepsis and bowel occlusion. Although the problem is very frequent, there is neither a clear definition nor consensus criteria to identify a "Complex Abdominal Wall Closure" (CAWC); in general, the term refers to an abdominal wall hernia that is technically challenging and time consuming [10]. The first aim should be to control immediate life-threatening events, such as hemorrhage, and to reduce post-operative complications. In the last year, the paradigm has shifted from a single definitive operation to staged procedure with a delayed reparative surgery once the patient has stabilized [1]. This approach has resulted in improved survival in the first few hours after traumatic injury. While several etiologies may result in the requirement for an OA, goals of care are similar in all cases: temporary coverage of the viscera, appropriate critical care to include fluid resuscitation and nutrition support, treatment of the underlying etiology, attempts at fascial coverage and prevention or treatment of complications [4,6,7]. Different techniques have been described to obtain those goals but up to now there has been no consensus about the gold standard. We reported our experience with the Bogotà bag, one of the most largely used approaches for the management of the open abdomen.

2. Case reports

In the last 7 years, in the Pediatric Surgery Units of "S. Orsola-Malpighi" Hospital in Bologna and of "San Camillo-Forlanini" Hospital in Rome, Italy, were treated four cases of CA due to intestinal obstruction and subsequent surgical complications.

Case 1: male, 11 years old, operated at the age of 6 for appendicular peritonitis and admitted to our department for intestinal obstruction. A surgical exploration with an extensive adhesiolysis and a subtotal omentectomy was needed. A new episode of intestinal obstruction required a new laparotomy 15 days later, with a finding of ileal volvulus

* Corresponding author. Operative Unit of Peditric Surgery, San Camillo Forlanini Hospital, Circonvallazione Gianicolense 87, 00152, Roma, Italy.
E-mail address: stefanotur@yhoo.it (S. Tursini).

https://doi.org/10.1016/j.epsc.2020.101471
Received 2 April 2020; Received in revised form 14 April 2020; Accepted 15 April 2020
Available online 25 April 2020
2213-5766/© 2020 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

with a massive ileal infarction and plastic peritonitis. A subtotal resection of the ileum was needed from 80 cm from the Treitz ligament to the ileocecal valve. In the intent to avoid an ACS, a Bogotá bag was realized and a second look after 24h allowed us to perform a jejunostomy and a definitive abdominal closure. A total parenteral nutrition (TPN) was started. Five months later the intestinal recanalization was scheduled, and after a difficult adhesiolysis, a jejune-colic anastomosis was performed. The immediate post-operative period was uneventful, the TPN was gradually suspended without short bowel syndrome. After 7 years of follow-up, the patient is good in health.

Case 2: male, 7 years old, operated at birth for malrotation and duodenal atresia, under treatment with corticosteroid for eosinophilic gastroenteritis, was admitted to our department for intestinal obstruction. At the surgical exploration, a diagnosis of ileal volvulus due to strong peritoneal adhesions was done. Two weeks later a new episode of intestinal obstruction required a second laparotomy with a difficult adhesiolysis and a subsequent edema of the intestinal wall. Due to the impossibility to easily close the abdomen and to avoid an ACS, a Bogotá bag was realized. During the second look, performed after 48 hours, a jejunal resection with jejune-jejunal anastomosis was necessary and the definitive closure of the abdominal wall was realized. The immediate post-operative period was uneventful and, after 6 years of follow-up, the patient is in a good condition.

Case 3: female 9 years old admitted to Emergency Department, in critical condition for long lasting peritonitis. After clinical stabilization she underwent open appendectomy. After 4 days from the previous operation, she was readmitted to the operation room due to intestinal occlusion, intense abdominal distension and biliary vomiting. At this time due to the intense bowel edema and distension, after the resolution of a midgut volvulus caused by peritoneal adhesion, a Bogotà bag was realized (Fig. 1). After 48 h of Intensive Care Unit stay, the Bogotà bag was removed and the primary abdominal closure was realized. After 3 years of follow up, patient is in a good condition.

Case 4: male 15 years old, was born affected by aesophageal atresia type 2 and treated at birth with cervicostomy and gastrostomy and subsequent aesophagocolonplasty. At the age of 13, a laparoscopic cholecystectomy was performed due to cholelithiasis. The patient was affected by schizophrenia. The patient came to our attention due to an intestinal obstruction; he underwent a laparotomy and an extensive adhesiolysis. The immediate postoperative course was complicated by a peritonitis due to an intestinal perforation; during the laparotomy, an ileal resection and an ileostomy were performed. Due to the peritoneal inflammation and the intestinal edema, a Bogotà bag was realized (Fig. 2) The post-operative period in the Intensive Care Unit (ICU) was characterized by a septic shock and an acute renal failure without severe consequences and a definitive primary abdominal closure was realized 9 days later. After 2 years of postoperative follow-up, the patient is in a good condition.

Fig. 1. Bogotà bag in 9 years old girl.

3. Discussion

There is no clear definition of CAWC although the problem is very frequent; the term is used by general surgeons to describe an abdominal wall hernia that is technically challenging and time consuming [10]. To date, there is not even a consensus about the criteria to define an abdominal wall closure as “complex”. Analyzing the different classification systems proposed, four categories of risk factors are found frequently and could be used to define and categorize the CAWC [1,4,5,10]:

a) “Defect size and location”: large hernia, lumbar/subcostal or lateral hernia localization, loss of domain >20%;
b) “Contamination and soft tissue condition”: infected wound, loss of substance, graft closure;
c) “Patient and risk factors”: old age, male gender, associated pathology;
d) “Clinical scenario”: emergency operation, extensive adhesiolysis, presence of entero-cutaneous fistula, closure after OA technique.

One of the most feared complications in a CAWC is the ACS, a potentially lethal result of uncontrolled IAH. IAH is defined as bladder pressure greater than 12–15 mmHg (normal pressure: 0–5 mmHg); when it reaches 25 mmHg and is associated with the dysfunction of one or more organs (i.e., heart, kidneys, lungs, and central nervous system), it is defined as ACS [3]. Primary ACS is associated with injuries or disease of the abdominal region and appears immediately after a surgical intervention. The secondary ACS is subsequent to extra-abdominal conditions, such as sepsis, burns and massive fluid resuscitations. The tertiary ACS occurs in patients that develop ACS following a prophylactic attempt to prevent ACS. Once the ACS has been detected, immediate decompression of the abdomen is required [1,3,5,11]. In order to prevent the potential complications related to the syndrome.

OA is a surgical treatment method in which an abdominal wall defect is created by deliberately leaving the peritoneal cavity open at the end of the abdominal surgery or by opening (or re-opening) the abdomen because of concern for the abovementioned clinical situations [6,7,12].

OA techniques were firstly applied to Damage Control Surgery (DCS) [5,6,13]. The medical practice of DCS was derived from military experience and consists in limited and rapid surgical interventions to initially control a hemorrhage and contamination with packing and a temporary

Fig. 2. Bogotà bag in 17 years old male.

closure, followed by appropriate critical care and subsequent deferred definitive operation once the patient has stabilized. These conditions may often occur in emergency surgery for critical patients, trauma, abdominal sepsis or bowel occlusion; in these circumstances, the surgeon should assess the most suitable surgical technique for the abdominal wall closure, the first aim being to control immediate life-threatening events and reduce post-operative complications [1,7]. Retrospective studies have shown a significant increase of survival in adult patients managed with OA but an onset of complications related to the technique previously unknown. Indeed, leaving the abdomen open is beneficial, when indicated, but can result in major complications such as fluid and protein loss, fistula formation (entero-cutaneous or entero-atmospheric fistula), loss of domain due to muscle/fascia retraction and infections (surgical site or intra-abdominal) [3,18].

Although primarily and widely used in general surgery, the OA technique with TAC is a well-known approach also in pediatric age. In fact, the Schuster technique or "silo technique" for big gastroschisis or omphalocele has been in use since 60' [19]; it consists in a silastic bag to contain the abdominal content in order to avoid a forced closure of the defect when there is a "loss of domain" of almost 20% with high risk of compartment syndrome and second look surgery [20]. Recent improvements in intensive care systems and in the technology and quality of materials have changed the approach to the OA and many different techniques with the use of different materials have been described. Techniques have evolved from a static approach of containing the abdominal viscera or allowing the abdominal wall to granulate, placing a skin graft, and developing an abdominal wall hernia to more dynamic systems that facilitate earlier closure of the fascia and abdominal wall; each method is characterized by different specific features in terms of control of fluid loss, frequency of dressing, reducing the risk of loss of domain, ease of use and cost [9]. The number of operations and the time interval between the temporary closure and the definitive one is not well defined either; anyway, even in case of different interval abdominal closure, the aim should be to create a tension-free closure of the abdomen without elevating Intra-Abdominal Pressure (IAP) to achieve a final abdominal closure preferable by restoration of fascia integrity [1,6,18,21].

A commonly used technique in past decades was the *Simple packing:* non-adherent wet gauzes or hydrophilic dressing were placed on the top of the abdominal contents at the end of the first operation [9]. The necessity for reconstructive surgery due to granulation and retraction of the wound and the high incidence of protein loss and entero-atmospheric fistula formations, have led us to abandon this technique. In *Skin-Only Closure technique* the surgeon uses the skin, by running suture or towel clips to contain the abdominal viscera. This procedure is easy and quick with minimal fluid and heat loss; on the other hand, it does give rise to the risk of visceral injuries, skin loss and IAH/ACS and for these reasons it is used only in selected cases [22,23].

In the *Patch or Mesh technique,* generally defined as *Fascial Closure Techniques* (FCT), the abdominal wall closure is obtained by interposing prosthetic materials that are sutured at the edges of the fascia and subsequently excised in the medial portion and re-sutured with an effective fascial approximation [24–34]. Prior to the introduction of biologic meshes in the late 1990's/early 2000's, synthetic meshes (both absorbable and non-absorbable) were the only available products for closing fascial defects that could not be closed primarily or covered with skin closure alone. The potential interactions between synthetic material and host, with the risk of complications, must be kept in mind when using a mesh. The use of a synthetic mesh is in general discouraged in contaminated or infected environments (relative contraindication) due to the high risk of mesh infection. The most widely used non-absorbable mesh is the Polytetrafluoroethylene (PTFE) patch, that is advantageous because it is non-adherent to the underlying bowel and presents a low fistula rate [30]. The absorbable material can be removed or left in place and is completely absorbed between 90 and 180 days, resulting generally in a ventral hernia [27,28,30]. Biological mesh is a type of absorbable patch; it derives from different types of tissue (bovine, porcine and human), that has been decellularized to leave an extracellular collagen matrix. This material acts as a regenerative system; initially, it causes an inflammatory response and subsequently it promotes remodeling, though fibroblast incorporation, collagen deposition and vascular infiltration. Due to its biocompatible nature, the mesh is wholly incorporated into the host tissue; to obtain a successful repair, its structure should not be degraded until this integration occurs [29–33]. Biological meshes generally don't induce a foreign body or immune response and are more resistant to infection. Some studies have been reported a higher hernia recurrence rate and after longer periods than synthetic mesh, even if the data are conflicting; no significant differences in the recurrence rate are found among several types of biological meshes (homograft or xenografts) whereas non-linked grafts show a higher incidence of recurrence but a lower rate of infections than linked ones [33,34].

The Wittmann patch or "artificial burr" is a type of dynamic patch closure technique that consists of two detachable components, a loop sheet and a closure one (Velcro-like closure); each side is sutured to the fascia and tightened every 24–48 h until the fascia is approximately 2–4 cm apart in order to allow primary closure [35,36].

The generally defined Negative Pressure Wound Therapy (NPWT) dressing is nowadays widely used for TAC. It was first described in 1995 with the name of "vacuum pack" by Barker et al. [37,38]. It is a dynamic FCT that consists of three or four layers: a perforated inert layer in contact with the viscera, a layer formedwith either sterile surgical towels or polyurethane foam with a suction system, a silicon drain layer placed above the towels/sponges and an adhesive sheet to cover the skin surrounding the wound and complete the vacuum seal. Different technical variations have been described starting with the initial description of Barker. All these systems, with application of negative pressure, allow the abdominal cavity to expand, contrasting the lateral retraction of abdominal musculature and minimizing loss of domain; furthermore, they provide good protection for the viscera and an excellent control and quantification of the peritoneal fluid and losses [43,44]. In some case series association of the NPWT with FCT is also described. The combination of techniques works in a synergic way allowing the approximation of the fascial edges to the midline without interfering with the abdominal content but seems to be expensive and complex and well-trained personnel is needed [45–47].

Bogotà bag is one of the most widely used techniques [48]. A large intravenous sterilized bag, sutured to the skin or abdominal fascia, ensures containment of the abdominal viscera; antibiotic soaked towels are applied on the line of suture and an iodine-impregnated adhesive plastic drape is used to cover. Every 24h the coverage is inspected and changed [49,50].

A post-operative course of a TAC is very complex and needs ICU admission. The patient requires constant monitoring due to the risk of bleeding, hypothermia, significant fluid loss, respiratory dysfunction and coagulopathy; moreover, abdominal dressing used for closure must to be changed, when necessary, with inspection every 48–72 hours of the abdominal contents both in ICU and in the operating theatre depending on the patient's risk factor and type of TAC [6,51]. Aggressive fluid administration may worsen edema, with potential increase in abdominal pressure and IAH/ACS onset; the use of colloid or hypertonic solutions and a serial measurement of bladder pressure (every 1–6 hours) can prevent these complications [52]. Mechanical ventilation and paralysis are not mandatory in an OA, even if most patients remain intubated due to critical underlying conditions; conversely, a light or deep sedation depending on the case is necessary to avoid TAC damage [4,6]. A prophylactic perioperative antibiotic treatment compared to prolonged antibiotic management seems to give the same results in terms of complication rate; in patients with complicated intra-abdominal infection no unique antibiotic schemes are suggested and therapy should be restricted to 5–7 days, as recommended by Surgical Infection Society Guidelines [53–55].

Unless there aren't other contraindications, enteral feeding is allowed in an OA and TAC and may be beneficial for decreased complication rates and increased closure rates. The protein intake should be higher than normal due to the loss of protein-rich peritoneal fluid. However, the difficult re-feeding in these patients, also caused by repeated and close fasts for dressing in the operating room, leads to the placement of enteral feeding tubes and parenteral nutrition integration [56–58].

OA management develops in three phases. The first phase is the "acute resuscitative phase", which comprises the first 24–48 hours after the initial injury that requires a TAC and close monitoring in ICU. The second period, the "intermediate resuscitation" or "early reconstructive phase", starts 48-h post-primary event and can last up to 10 days: during this phase the risk of complications is low, and a primary abdominal closure should be attempted. The last phase, "the late reconstruction phase", is the period which elapses between 10-days post-injury and the primary or secondary closure of the abdominal wall [1].

In principle, the longer the abdomen remains open, the more difficult the primary closure will be due to fascial retraction, intestinal adhesions and the onset of complications [59]. Furthermore, early fascial closure is associated with the best functional outcome in the long-term [60,61].

A component separation of the abdominal wall layers may be considered in the reconstruction of very large abdominal wall defects to provide a fascial apposition using autogenous tissue. The *Component Separation Technique* is based on the evidence that separation of the muscle components of the abdominal wall allows mobilization of each unit greater than possible by mobilization of the abdominal wall "en bloc". This method uses bilateral, innervated rectus muscle and fascia flap complexes (abdominis-transversus and abdominis-internal oblique muscle flap) transposed medially to reconstruct the central abdominal wall [62].

Fascial bridge technique consists in the use of prosthesis (synthetic or biologic mesh) to bridge the gap between the edges of the fascial defect. The use of permanent non-absorbable prosthetic mesh has been abandoned because of the high rates of complications (infection, enterocutaneous fistula, recurrent herniation, mesh extrusion). Conversely, a biologic mesh has the capacity to integrate with surrounding tissues, with less incidence of complications when compared with synthetic materials; it performs the function of scaffolding for the granulation tissue to form new fascial tissue, with future skin grafting and planned ventral hernia [63,64].

A skin abdominal coverage in a planned ventral hernia may be achieved with two techniques: skin-only closure, previously described, and split-thickness skin graft. In the last technique, the granulation tissue that has formed above the abdominal viscera is covered by a skin graft, using an absorbable mesh if necessary; 6–12 months is usually necessary before trying an elective hernia repair, also to allow the underlying inflammatory process of regressing [65].

Analyzing the literature to compare all of the TAC methods described previously, it emerges that the optimal approach for management of OA doesn't exist and the best approach is the one most suitable for that specific clinical situation. An important distinction must be made between an infected and a non-infected field. In the first case, the Wittmann patch and the NPWT therapy had the best outcome followed by meshes; in the field of infected/contaminated abdomen, NPWT techniques are the protagonists. The Wittmann patch allows a rapid and safe reentry into the abdomen tore-exploration and a gradual approximation of the fascia with possible adjustments according to IAP. It has a high rate of delayed primary closure with a low rate of overall complications thanks to its dynamic fascial closure mechanism; on the other hand, it is very costly, does not permit good evacuation of the peritoneal fluid and wound drainage and the fascial suturing could increase the fascial trauma, necrosis and future incisional hernia [35,36]. NPWT techniques are associated with significantly higher 30-day primary fascial closure rates and lower 30-day all-cause mortality rates among patients who require an OA for at least 48 hours. The role of NPWT therapy in the infected/contaminated field is based on the efficient removal of peritoneal fluid, containing all inflammatory mediators and bacteria, and promotion of systemic inflammatory response and granulation tissue formation. In the presence of sepsis, these techniques have the highest delayed primary closure rate and the lower mortality and fistula rate. Among all, the ABThera system seems to have the best performance, thanks to smaller negative pressures produced on the bowel loops, with a lower rate of fistula. NPWT combined with meshes show an improvement in the primary fascial closure rates [39–47]. The advantages of mesh closure include ease of placement and facilitation of re-exploration; disadvantages include the risk of fascial necrosis that may impair future primary fascial closure and the high cost. The synthetic mesh may be associated with complications due to foreign material reactions and mesh infection, whereby it shouldn't be used in contaminated/infected fields. Out of them all the absorbablemesh has a higher resistance to infections, though it is encumbered by a high risk of fistula formation and is always related to a large ventral hernia; for these reasons, in addition to the high cost and the difficulty in finding biological material, the biological mesh should be implanted only in contaminated or potentially contaminated (presence of stoma, gastro-intestinal perforation, history of mesh infection) surgical fields or in fascial bridge techniques. Given the lack of experience on the use of biological patches in pediatric age in OA techniques, further randomized studies are necessary to evaluate the long-term results and the right indication for the use of biological prosthesis rather than a synthetic one [24–34].

In the Bogota bag technique, the use of an almost inert and non-adhesive material minimizes fluid and heat loss, reduces trauma on the viscera and permits an easy control of the IAP with a very low rate of entero-cutaneous fistula. The technique is simple, low cost and the semitransparent coverage allows visual inspection of the viscera; it is strongly recommended in the rural region to stabilize the patient and safely transfer him to a major hospital. On the other hand, the Bogotà bag doesn't permit good removal of abdominal fluids, doesn't prevent retraction of the abdominal wall and is burdened by a high rate of delayed complications such as ventral hernia. It should be used in cases at risk of intra-abdominal bleeding, in which case itprovides closure within 2 or 3 days, as in our cases [49,50].

4. Conclusion

OA is managed with TAC using one of several techniques, followed by intervalled abdominal closure, preferably by bringing the edges of the abdominal fascia together primarily (primary closure) or, if this is not feasible, using a functional closure or simple coverage. The goal of TAC is to create a tension-free closure of the abdomen without elevating IAP. The Bogotà bag is only one of the many described approaches. Pediatric surgeons are used to dealing with this kind of approach; the Schuster or Silo technique for big gastroschisis or omphalocele is quite similar to the Bogotà bag technique. In our experience, the Bogotà bag in OA management represents a feasible and reproducible technique which is cheaper than other ones and doesn't require a particularly well trained équipe. It should be used in selected cases, particularly where there is the need of a visual inspection of abdominal viscera and in cases of high risk of intra-abdominal bleeding or intestinal suffering and necrosis. This approach should be limited to those cases where the primary closure can be planned in a short period, normally no longer than 7 days.

Patient consent

"Consent to publish the case report was not obtained. This report does not contain any personal information that could lead to the identification of the patient."

Funding

"No funding or grant support."

Authorship

All authors attest that they meet the current ICMJE criteria for Authorship.

Declaration of competing interest

The authors declare that they have no conflict of interest.

References

[1] Kaplan M, Banwell P, Orgill DP, et al. Guidelines for the management of the open abdomen. Wounds 2005;17(supplement 1):1–24.
[2] Ghazi B, Deigni O, Yezhelyev M, Losken A. Current options in the management of complex abdominal wall defects. Ann Plast Surg 2011 May;66(5):488–92.
[3] Beckman M, Paul J, Neideen T, Weigelt JA. Role of the open abdomen in critically ill patients. Crit Care Clin 2016 Apr;32(2):255–64.
[4] Open Abdomen Advisory Panel, Campbell A, Chang M, Fabian T, Franz M, Kaplan M. Management of the open abdomen: from initial operation to definitive closure. Am Surg 2009 Nov;75(11 Suppl):S1–22.
[5] 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.
[6] Regner JL, Kobayashi L, Coimbra R. Surgical strategies for management of the open abdomen. World J Surg 2012 Mar;36(3):497–510.
[7] Fernández LG. Management of the open abdomen: clinical recommendations for thetrauma/acute care surgeon and general surgeon. Int Wound J 2016 Sep;13 (Suppl 3):25–34.
[8] Demetriades D, Salim A. Management of the open abdomen. Surg Clin 2014 Feb;94 (1):131–53.
[9] Quyn AJ, Johnston C, Hall D, Chambers A, Arapova N, Amin Al, et al. The open abdomen and temporary abdominal closure systems–historical evolution and systematic review. Colorectal Dis 2012 Aug;14(8):e429–38. https://doi.org/10.1111/j.1463-1318.2012.03045.x.
[10] Slater NJ, Montgomery A, Berrevoet F, Carbonell AM, Chang A, Franklin M, Kercher KW, Lammers BJ, Parra-Davilla E, Roll S, Towfigh S, van Geffen E, Conze J, van Goor H. Criteria for definition of a complex abdominal wall hernia. Hernia 2014 Feb;18(1):7–17.
[11] Kirkpatrick AW, Roberts DJ, De Waele J, Jaeschke R, Malbrain ML, De Keulenaer B, Duchesne J, Bjorck M, Leppaniemi A, Ejike JC, Sugrue M, Cheatham M, Ivatury R, Ball CG, Reintam Blaser A, Regli A, Balogh ZJ, D'Amours S, Debergh D, Kaplan M, Kimball E, Olvera C. Pediatric guidelines sub-committee for the world society of the abdominal compartment Syndrome.*Intra-abdominal hypertension and theabdominal compartment syndrome: updated consensus definitions and clinicalpractice guidelines from the world Society of the abdominal compartment syndrome*. Intensive Care Med 2013 Jul;39(7):1190–206.
[12] Friese RS. The open abdomen: definitions, management principles, and nutrition support considerations. Nutr Clin Pract 2012 Aug;27(4):492–8. Epub 2012 Jun 19. Review.
[13] Diaz Jr JJ, Cullinane DC, Dutton WD, Jerome R, Bagdonas R, Bilaniuk JW, Collier BR, Como JJ, Cumming J, Griffen M, Gunter OL, Kirby J, Lottenburg L, Mowery N, Riordan Jr WP, Martin N, Platz J, Stassen N, Winston ES. The management of the open abdomen in trauma and emergency general surgery: part 1-damage control. J Trauma 2010 Jun;68(6):1425–38.
[18] Earle D, Roth JS, Saber A, Haggerty S, Bradley 3rd JF, Fanelli R, Price R, Richardson WS, Stefanidis D, Sages Guidelines Committee. SAGES guidelines for laparoscopic ventral hernia repair. Surg Endosc 2016 Aug;30(8):3163–83.
[19] Diaz Jr JJ, Cullinane DC, Khwaja KA, Tyson GH, Ott M, Jerome R, et al. Eastern Association for the Surgery of Trauma: management of the open abdomen, part III-review of abdominal wall reconstruction. J Trauma Acute Care Surg 2013 Sep;75 (3):376–86.
[20] Feliciano DV, Burch JM. Advances in trauma and critical care, vol. 6. St. Louis, Mo, USA: Mosby-Year Book; 1991. p. 235–50. Towel clips, silos and heroic forms of wound closure.
[21] Tremblay LN, Feliciano DV, Schmidt J, et al. Skin only or silo closure in the critically ill patient with an open abdomen. Am J Surg 2001;182(6):670–5.
[22] Fansler RF, Taheri P, Cullinane C, Sabates B, Flint LM. Polypropylene mesh closure of the complicated abdominal wound. Am J Surg 1995;170(1):15–8.
[23] Nagy KK, Fildes JJ, Mahr C, et al. Experience with three prosthetic materials in temporary abdominal wall closure. Am Surg 1996;62(5):331–5.
[24] Ciresi DL, Cali RF, Senagore AJ. Abdominal closure using nonabsorbable mesh after massive resuscitation prevents abdominal compartment syndrome and gastrointestinal fistula. Am Surg 1999;65(8):720–5.
[25] Howdieshell TR, Proctor CD, Sternberg E, Cué JI, Mondy JS, Hawkins ML. Temporary abdominal closure followed by definitive abdominal wall reconstruction of the open abdomen. Am J Surg 2004;188(3):301–6.
[26] Prichayudh S, Sriussadaporn S, Samorn P, et al. Management of open abdomen with an absorbable mesh closure. Surg Today 2011;41(1):72–8.
[27] Yuan Y, Ren J, Zhang W, Chen J, Li J. The effect of different temporary abdominal closure materials on the growth of granulation tissue after the open abdomen. J Trauma Inj Infect Crit Care 2011;71(4):961–5.
[28] FitzGerald JF, Kumar AS. Biologic versus synthetic mesh reinforcement: what are the pros and cons? Clin Colon Rectal Surg 2014 Dec;27(4):140–8.
[29] Primus FE, Harris HW. A critical review of biologic mesh use in ventral herniarepairs under contaminated conditions. Hernia 2013 Feb;17(1):21–30.
[30] Slater NJ, van der Kolk M, Hendriks T, van Goor H, Bleichrodt RP. Biologic grafts for ventral hernia repair: a systematic review. Am J Surg 2013 Feb;205(2):220–30. submitted for publication.
[31] Latifi R. Practical approaches to definitive reconstruction of complex abdominal wall defects. World J Surg 2016 Apr;40(4):836–48.
[32] Mulder IM, Deerenberg EB, Bemelman WA, Jeekel J, Lange JF. Infection susceptibility of crosslinked and non-crosslinked biological meshes in an experimental contaminated environment. Am J Surg 2015 Jul;210(1):159–66.
[33] Wittmann DH, Aprahamian C, Bergstein JM, Edmiston CE, Frantzides CT, Quebbeman EJ, Condon RE. A burr-like device to facilitate temporary abdominal closure in planned multiple laparotomies. Eur J Surg 1993 Feb;159(2):75–9.
[34] Weinberg JA, George RL, Griffin RL, Stewart AH, Reiff DA, Kerby JD, Melton SM, Rue 3rd LW. Closing the open abdomen: improved success with Wittmann Patch staged abdominal closure. J Trauma 2008 Aug;65(2):345–8.
[35] Brock WB, Barker DE, Burns RP. Temporary closure of open abdominal wounds: the vacuum pack. Am Surg 1995 Jan;61(1):30–5.
[36] Barker DE, Green JM, Maxwell RA, Smith PW, Mejia VA, Dart BW, Cofer JB, Roe SM, Burns RP. Experience with vacuum- pack temporary abdominal wound closure in 258 trauma and general and vascular surgical patients. J Am Coll Surg 2007 May;204(5):784–92. discussion 792-3.
[37] Miller PR, Meredith JW, Johnson JC, Chang MC. Prospective evaluation of vacuum-assisted fascial closure after open abdomen: planned ventral hernia rate is substantially reduced. Ann Surg 2004 May;239(5):608–14. discussion 614-6.
[38] Cheatham ML, Demetriades D, Fabian TC, Kaplan MJ, Miles WS, Schreiber MA, Holcomb JB, Bochicchio G, Sarani B, Rotondo MF. Prospective study examining clinical outcomes associated with a negative pressure wound therapy system and Barker's vacuum packing technique. World J Surg 2013 Sep;37(9):2018–30.
[39] Suliburk JW, Ware DN, Balogh Z, McKinley BA, Cocanour CS, Kozar RA, Moore FA, Ivatury RR. Vacuum-assisted wound closure achieves early fascial closure of open abdomens after severe trauma. J Trauma 2003 Dec;55(6):1155–60. discussion 1160-1.
[40] Cothren CC, Moore EE, Johnson JL, Moore JB, Burch JM. One hundred percent fascial approximation with sequential abdominal closure of the open abdomen. Am J Surg 2006 Aug;192(2):238–42.
[41] Fitzgerald JEF, Gupta S, Masterson S, Sigurdsson HH. Laparostomy management using the ABThera open abdomen negative pressure therapy system in a grade IV open abdomen secondary to acute pancreatitis. Int Wound J 2013;10(2):138–44.
[42] Delgado A, Sammons A. In vitro pressure manifolding distribution evaluation of ABThera(™) Active Abdominal Therapy System, V.A.C.(®) Abdominal Dressing System, and Barker's vacuum packing technique conducted under dynamic conditions. SAGE Open Med 2016 Jan 18;4. 2050312115624988.
[43] Willms A, Schaaf S, Schwab R, Richardsen I, Bieler D, Wagner B, Güsgen C. Abdominal wall integrity after open abdomen: long-term results of vacuum-assisted wound closure and mesh-mediated fascial traction (VAWCM). Hernia 2016 Dec;20(6):849–58.
[44] Willms A, Schaaf S, Schwab R, Richardsen I, Jänig C, Bieler D, et al. Intensive care and health outcomes of open abdominal treatment: long-term results of vacuum assisted wound closure and mesh-mediated fascial traction (VAWCM). Langenbeck's Arch Surg 2017 Apr 5;402(3):481–92. https://doi.org/10.1007/s00423-017-1575-8. Epub 2017 Apr 5.
[45] Petersson U, Acosta S, Björck M. Vacuum-assisted wound closure and mesh-mediated fascial traction—a novel technique for late closure of the open abdomen. World J Surg 2007;31(11):2133–7.
[46] Mattox KL. *Introduction, background, and future projections of damage control surgery*. Surg Clin 1997 Aug;77(4):753–9.
[47] Karakose O, Fatih Benzin M, Pülat H, Zafer Sabuncuoglu M, Eken H, Zihni I, Barut I. Bogota bag use in planned Re-laparotomies. Med Sci Mon Int Med J Exp Clin Res 2016 Aug 17;22:2900–4.
[48] Fernandez L, Norwood S, Roettger R, Wilkins 3rd HE. Temporary intravenous bag silo closure in severe abdominal trauma. J Trauma 1996 Feb;40(2):258–60.
[49] Wyrzykowski AD, Feliciano DV. Trauma damage control. In: Feliciano DV, Mattox KL, Moore EE, editors. Trauma. sixth ed. New York Chicago San Francisco: McGraw-Hill Companies; 2008. p. 851–70.
[50] Bradley M, Galvagno S, Dhanda A, Rodriguez C, Lauerman M, DuBose J, Scalea T, Stein D. Damage control resuscitation protocol and the management of open abdomens in trauma patients. Am Surg 2014 Aug;80(8):768–75.
[51] Dutton WD, Diaz Jr JJ, Miller RS. Critical care issues in managing complex open abdominal wound. J Intensive Care Med 2012 May-Jun;27(3):161–71.
[52] Teixeira PG, Salim A, Inaba K, Brown C, Browder T, Margulies D, Demetriades D. A prospective look at the current state of open abdomens. Am Surg 2008 Oct;74 (10):891–7.
[53] Mazuski JE, Tessier JM, May AK, Sawyer RG, Nadler EP, Rosengart MR, Chang PK, O'Neill PJ, Mollen KP, Huston JM, Diaz Jr JJ, Prince JM. The surgical infection society revised guidelines on the management of intra-abdominal infection. Surg Infect 2017 Jan;18(1):1–76.
[54] Byrnes MC, Reicks P, Irwin E. Early enteral nutrition can be successfully implemented in trauma patients with an "open abdomen". Am J Surg 2010 Mar;199 (3):359–62. discussion 363.

[55] McClave SA, Saad MA, Esterle M, Anderson M, Jotautas AE, Franklin GA, Heyland DK, Hurt RT. Volume-based feeding in the critically ill patient. JPEN - J Parenter Enter Nutr 2015 Aug;39(6):707–12.
[56] Hourigan LA, Linfoot JA, Chung KK, Dubick MA, Rivera RL, Jones JA, Salinas RD, Mann EA, Wade CE, Wolf SE, Baskin TW. Loss of protein, immunoglobulins, and electrolytes in exudates from negative pressure wound therapy. Nutr Clin Pract 2010 Oct;25(5):510–6.
[57] Pommerening MJ, DuBose JJ, Zielinski MD, Phelan HA, Scalea TM, Inaba K, Velmahos GC, Whelan JF, Wade CE, Holcomb JB, Cotton BA, Aast Open Abdomen Study Group. Time to first take-back operation predicts successful primary fascial closure in patients undergoing damage control laparotomy. Surgery 2014 Aug;156 (2):431–8.
[58] Fox N, Crutchfield M, LaChant M, Ross SE, Seamon MJ. Early abdominal closure improves long-term outcomes after damage-control laparotomy. J Trauma Acute Care Surg 2013 Nov;75(5):854–8.
[59] Miller RS, Morris Jr JA, Diaz Jr JJ, Herring MB, May AK. Complications after 344 damage-control open celiotomies. J Trauma 2005 Dec;59(6):1365–71. discussion 1371-4.
[60] Ramirez OM, Ruas E, Dellon AL. Components separation" method for closure of abdominal-wall defects: an anatomic and clinical study. Plast Reconstr Surg 1990 Sep;86(3):519–26.
[61] Voyles CR, Richardson JD, Bland KI, Tobin GR, Flint LM, Polk Jr HC. Emergency abdominal wall reconstruction with polypropylene mesh: short-term benefits versus long-term complications. Ann Surg 1981;194(2):219–23.
[62] Burger JWA, Luijendijk RW, Hop WCJ, et al. Long-term follow-up of a randomized controlled trial of suture versus mesh repair of incisional hernia. Ann Surg 2004; 240(4):578–85.
[63] Fabian TC, Croce MA, Pritchard FE, Minard G, Hickerson WL, Howell RL, Schurr MJ, Kudsk KA. Planned ventral hernia. Staged management for acute abdominal wall defects. Ann Surg 1994 Jun;219(6):643–50. discussion 651-3.