Optimum Methods for Keeping the Abdomen Open

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Abstract

Purpose of Review Damage control laparotomy, also known as an “open abdomen,” is a life-saving maneuver frequently used to treat severely injured and emergency general surgery patients.

Recent Findings Several techniques exist to keep the abdomen open; temporary abdominal closure methods have evolved over time from inexpensive, simple techniques to more advanced methods utilizing commercially available products with improving results.

Summary In this review, we describe the techniques of open abdomen management along with their advantages and drawbacks as well as advanced management of patients with open abdomens.

Keywords Open abdomen · Temporary abdominal closure · Damage control laparotomy

Introduction

Damage control laparotomy (DCL), also known as “open abdomen, OA,” refers to the surgical technique where the abdominal cavity is entered and left open deliberately at the

completion of an abdominal exploration [1]. Most commonly described in trauma patients, DCL is a life-saving maneuver in which the surgeon accepts that portions of the procedure will not be completed [2]. This technique ensures hemorrhage and sepsis source control has been obtained to the best of the surgeon’s ability. Once the abdominal domain has been maintained, albeit temporarily, the patient is rapidly transferred to the intensive care unit (ICU) for ongoing resuscitation [3, 4]. Re-exploration and definitive treatment of injuries are usually undertaken within 24–72 h of the index operation.

The use of packing to manage hepatic hemorrhage was originally described by Pringle and Halsted in their respective landmark papers in 1908 and 1913 [5, 6]. Their technique was widely adopted through World War II when primary repair re-emerged as standard of care due to emerging improvements in surgical technique and resources [7]. The late 1970s and early 1980s saw resurgence in the use of DCL [5, 6]. OA in the setting of emergency general surgery (EGS), specifically for acute suppurative peritonitis, was described by Steinberg in 1979 [8]. Following his publication, several reports described management of infected pancreatic necrosis with open abdomen management [9, 10].

Furthermore, in a prospective evaluation to treat liver injuries, Lucas and Ledgerwood reported acceptable outcomes for treating major hepatic injuries using similar techniques [11]. In the modern era, the concept of damage control resuscitation and utilization of open abdomen in trauma was popularized by Rotondo and Moore in the early 1990s [12, 13]. After dissemination of their source control methods coupled with early resuscitation in the ICU, DCL gained widespread acceptance. As a result of this popularity, multiple techniques to facilitate re-exploration have been developed. To this date, there is absence of Level I evidence data about optimal management of patients with open abdomen. This has led to multi-institutional and worldwide collaborations to help us better understand and

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improve care for this patient population [14]. It is the aim of this chapter to describe the techniques of open abdomen management along with their advantages and drawbacks.

Risks Associated with the Open Abdomen

When the decision is made to abbreviate the procedure and keep the abdomen open, the surgeon must start thinking about timing and method of achieving closure, as there are many risks associated with OA. Fluid loss from open abdomen is estimated to be 1 cc/kg per hour [15]. Each liter removed contains 2 g of protein, leading to a significant nutritional loss in the critically ill patient [16]. Hypothermia is another major complication which may aggravate acidosis and coagulopathy. Coverage of the viscera prevents heat loss due to evaporation and radiation, and is associated with improved outcomes [17, 18]. Loss of domain, which can lead to failure of fascial closure and development of ventral hernia, is another major risk of OA. Failure of primary fascial closure can result in surgical site infection and enterocutaneous fistulae formation, leading to significant morbidity [19–21].

Techniques

Several techniques exist to keep the abdomen open. Ideally, these temporary abdominal closure (TAC) techniques should provide several features: (1) rapid access to the peritoneal cavity for re-exploration, (2) tension-free fascial closure to prevent rise in intra-abdominal pressure, (3) facilitate fascial closure at the appropriate time, and (4) serve as a barrier to the external environment while safely covering the abdominal viscera and preventing fluid losses [22, 23]. TAC methods have evolved over time from inexpensive, simple techniques to more advanced methods utilizing commercially available products. While there is a lot of literature reported for types of TAC, there are relatively few studies which directly compare techniques. In fact, there are limited Level I recommendations in this field with only limited number of randomized trials comparing various TAC techniques [24•, 25•, 26•, 27, 28, 29•, 30•]. In a multi-institutional, randomized trial, we evaluated the effect of chemically induced paralysis of the lateral abdominal wall on primary fascial closure rates. Patients were randomized to ultrasound-guided injections of their abdominal wall muscles with either Botox or placebo. Primary fascial closure rates were high in both groups: 96 % for Botox and 93 % for placebo [31, 32•].

Skin Re-approximation

Re-approximating the skin is the simplest, cheapest method of achieving TAC. While there are multiple methods to facilitate skin closure, the most common uses skin suturing with a

running monofilament or perforating towel clamps placed along the length of the abdominal incision [33, 34]. The clamp points are placed into the skin on both sides of the open incision and spaced 1 to 2 cm apart (Fig. 1). This method, although relatively straightforward to accomplish, has many disadvantages. Fixed approximation of the skin without the ability to drain excess abdominal fluid may result in increased intra-abdominal pressure, especially during the resuscitation phase of damage control [35]. Additionally, injury to the skin edges can increase the risk of infection. Perhaps most importantly, the abdominal wall fascia is not re-approximated which can result in a loss of abdominal domain making the definitive closure more challenging [36]. Other disadvantages include extra nursing care if peritoneal fluid leaks between the skin edges. For these reasons, the authors do not recommend this technique unless no other option is available.

The Silo Closure (aka “Bogota Bag”)

The Bogota Bag technique, originally described by surgeons in Bogota, Columbia, is performed using a pre-sterilized, 3-l plastic cystoscopy fluid irrigation bag. The bag is cut open, tailored to size, and sutured or stapled to the skin (Fig. 2) [38]. The technique was widely adopted in the past due to ease of application, broad availability, and low cost. Similarly to the skin re-approximation technique, Bogota Bag closure does not allow for the removal of excess peritoneal fluid thereby increasing the risk of intra-abdominal hypertension and abdominal compartment syndrome as well as increasing the challenges for nursing staff trying to keep the patient’s abdominal skin dry. Again, loss of abdominal domain and skin trauma remain other potential complications. A modification has been made to this technique to overcome these issues. Rather than a single bag, two plastic IV bags, one placed between the viscera and abdominal wall, and one sutured to the skin, can be used. Trans-fascial sutures between the bags function as dynamic retention sutures to prevent abdominal domain loss

Fig. 1 Towel-clip closure. Reprinted from Qian Huang et al. [23], p. 15

Fig. 2 Bogotá bag. Reprinted with permission from Rutherford et al. [37]

[39]. Reported primary fascial closure rate using this technique varies, but can be as high as 82 % [36, 40, 41]. Moreover, long-term ventral hernia occurrence can be present in up to 60 % of patients [42]. In a limited-resource environment where no other alternatives exist, the Bogota Bag TAC technique may be a viable option.

Wittmann-Patch® (NovoMedicus, Germany)

This technique achieves TAC by suturing two patches to each side of the fascia with a non-absorbable suture. The two sheets adhere to each other with a Velcro-like mechanism as one sheet consists of micro-mushrooms (i.e., hooks) and the second is made up of multiple slings which catch and hold the micro-mushrooms [43]. This provides easy access for re-exploration. A primary advantage of this technique is that it allows for serial re-approximation of the fascia by tightening the patch and cutting off the excess material. Eventually, the fascia will be mobilized sufficiently to the midline to allow for primary fascial closure. These serial tightening procedures can even be performed in the patient's bed in intensive care unit [44]. In a retrospective review, the technique was associated with an improved delayed primary fascial closure rate by 48 % over other various TAC techniques (i.e., silo, vac-pack, absorbable mesh) [45•]. Primary fascial closure rate has even been reported to be as high as 94 % [46]. One of the disadvantages of this method is tissue injury due to excessive tension on the fascial edges. As a result, fascial inflammation and necrosis may ensue, which may hinder the healing process, and increase rates of ventral herniae [24•, 46]. Long-term data on hernia rates after primary fascial closure using the Wittmann-Patch is lacking.

Mesh Closure

Permanent, biologic, and synthetic absorbable mesh prostheses can be used to achieve TAC. The method of closure is similar no matter the type of mesh utilized; the mesh is circumferentially sutured to the rectus abdominus fascial edges using running or interrupted sutures (Fig. 3) [48–50,

Fig. 3 Polytetrafluoroethylene (ePTFE) mesh used to cover abdominal contents. Reprinted with permission from Robin-Lersundi et. al. [47]

51•]. A negative pressure dressing is generally applied to provide extra tension and facilitate the removal of excessive peritoneal fluid. Mesh closure is relatively easy to perform, enables rapid access to the abdominal cavity, prevents retraction of the abdominal fascia, and improves primary fascial closure rates. Primary fascial closure rates have been reported to be up to 89 % when using permanent mesh [50]. Permanent mesh, however, is not generally recommended to facilitate PFC as enterocutaneous fistula formation rate is high, up to 50 % [48, 52]. Polytetrafluoroethylene (PTFE) may be an exception, however, as bowel and other intra-abdominal viscera do not tend to adhere and there appears to be a low risk of enterocutaneous fistula formation [53]. Polypropylene mesh may be more resistant to infection and allows for skin grafting, while PTFE mesh does not. GORE-TEX® DUALMESH® has also been used to manage the OA [54]. The mesh does not adhere to the underlying bowel, but is expensive, cannot be used in infected fields, and lacks porosities which do not allow for fluid removal. Biologic mesh has also been used. In a prospective case series of 10 patients with OA managed with Human Acellular Dermal Matrix (Alloderm®, Lifecell), infection and enterocutaneous rates were low. However, all patients developed ventral hernia at 1 year follow-up [55]. Lastly, the only randomized controlled trial studying two different methods of TAC compared Polyglactin 910 (Vicryl®) to negative pressure dressing. There were no differences between the two techniques in delayed primary fascial closure rates, negative pressure (31 %) and mesh (26 %). Although not statically significant, complication rate, specifically enterocutaneous fistula, was higher in patients treated with negative pressure dressing (21 %) compared to mesh (5 %) [30•].

Negative Pressure TAC

Negative pressure therapy is done using a vacuum device. There are both commercial and non-commercial options created out of items commonly available in the operating room. First described by Barker and colleagues, the vacuum pack is constructed in layers: a porous 1010 3 M™ Steri-Drape™ sheet is placed underneath the peritoneum to cover the viscera, a surgical towel or KERLIX™ gauze over the sheet, Jackson-Pratt (JP) drains, an adhesive drape 3 M™ Ioban™ to cover the entire wound [56]. The JP drains are connected to a wall suction outlet which provided continuous negative pressure. This method is relatively cheap, easily applied, and easy to make if commercial devices are not readily available. The main drawback of this technique is decreased primary fascial closure rates and unequal distribution of suction throughout the abdominal cavity, leading to intra-abdominal fluid accumulation. In a single-institution retrospective review, the primary fascial closure rate using this method was 52 % [56].

In 2001, Garner and colleagues reported use of the KCI Vacuum-Assisted Closure System for TAC, a polyurethane foam sponge was utilized as a substitute to surgical towel over the Steri-Drape™ barrier into which suction tubing was connected [57]. The authors reported a primary fascial closure rate of 92 %, but this experience was limited by small patient population. Miller and colleagues were able to show similar outcomes [58]. Caution must be taken to avoid direct contact between sponge and bowel, as this may result in erosion of the bowel wall and fistula formation. Newer generation of vacuum-assisted closure system consists of a non-adherent fenestrated polyurethane drape for protection of viscera (Fig. 4). Prospective evaluation has revealed rates of primary fascial closure ranging from 69 to 82 % [59]. In vitro study evaluating pressure distribution between three negative pressure TAC techniques revealed that approaches to negative pressure therapy for open abdomen treatment are not equal. The study suggests that newer commercially available devices have better pressure distribution, the clinical implications of this finding is yet to be determined [60].

Dynamic Retention Sutures

Several methods of retention sutures have been described, often used in conjunction with negative pressure TAC. Trans-fascial sutures are placed to provide continuous medial tension on the abdominal wall, thus preventing lateral retraction. This can be achieved using vessel loops or heavy non-absorbable suture material. Studies have shown an increased rate of fascial closure. In a report of 100 consecutive patients treated with vacuum-assisted closure and no. 1-polydioxanone (PDS) sutures, primary fascial closure was achieved in all patients [61•]. In another retrospective review, delayed primary fascial closure rate was 87 % with low

Fig. 4 ABThera™ open abdomen negative pressure therapy

infection (4 %) and enterocutaneous rates (3 %) [62]. Additionally, a retrospective study of 16 OA patients treated with continuous retention sutures showed complete fascial closure in 82 % of patients [63]. Given these encouraging results and low complication rates, retention sutures are routinely placed in our practice.

Clinical Management of Patients with Open Abdomen

Intra-abdominal hypertension and acute abdominal compartment syndrome are very common in trauma and critically ill patients. If left untreated, mortality from this condition is high [64, 65]. In a prospective study, 33 patients with abdominal compartment syndrome were treated with decompressive laparotomy. Having the abdomen open resulted in immediate reduction in intra-abdominal pressure and significant improvement in end organ perfusion and function [66]. When acute compartment syndrome is suspected, the diagnosis can be confirmed with measurement of bladder pressure [67].

The ultimate goal of TAC is to improve the odds of mortality for emergency surgical and trauma patients by abbreviated laparotomy and rapid reversal of acidosis, hypothermia, and coagulopathy using damage control resuscitation. A major secondary goal of this process, however, is to ensure delayed primary fascial closure. The techniques outlined above

all will facilitate these goals to varying degrees. While these techniques are necessary, they are not sufficient. There are adjuncts to these techniques which may increase the rates of primary fascial closure to the greatest rate possible.

All institutions which have the possibility of performing damage control surgery must have a protocol in place outlining the steps needed to facilitate the original TAC. This protocol must extend into the immediate post-operative period by outlining the timing and technique of abdominal re-exploration. With this type of an approach, rates nearing 100 % primary fascial closure are possible when the protocol is adhered to [61••]. A large portion of this success may be attributable to planned serial re-exploration at every 48 h. When this was not done, rates of primary fascial closure plummeted to 55 %. In the largest prospective, multi-institutional trial to date of trauma patients undergoing TAC, every hour delay in re-exploration decreased the risk of primary fascial closure by 1.1 % [68••]. Moreover, leaving the abdomen open for a longer period increases the risk of microbial colonization of the wound. But this has not been shown to increase wound complications or enterocutaneous fistula formation [69].

Excessive fluid administration can lessen rates of primary fascial closure. Out of 181 non-trauma patients undergoing TAC management, patients who did not achieve primary fascial closure had a greater cumulative fluid balance through post-operative day 10 [70]. This excessive rate of fluid administration was linked temporally to the development of sepsis and other infectious complications including intra-abdominal abscess and enterocutaneous fistula formation. Avoiding these complications may lower fluid requirements thereby increasing primary fascial closure rates. Previously thought of an anathema enteral feeding in the setting of TAC has been shown to be safe and associated with lower rates of infectious complications including pneumonia [71•]. While the mechanism for this benefit of feeding remains unknown, it is theorized that enteral feeding provides trophic factors critical in maintaining tight junctions of the gastrointestinal mucosa [72].

Conclusion

There are many methods surgeons can use to keep the abdomen open. While the primary goal of these TAC techniques is to improve mortality for critically ill surgical patients by facilitating damage control resuscitation, obtaining primary fascial closure once the critical illness has been successfully treated remains paramount. Not only is the correct utilization of TAC techniques necessary to ensure the highest rates of primary fascial closure, but also the continued involvement of the surgeon via protocols and avoidance of complications is critical.

Compliance with Ethical Standards

Conflict of Interest Drs. Khasawneh and Zielinski declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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