Open Abdomen and Temporarily Abdominal Closure

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Abstract

Aggressive resuscitation combined with staged surgery in severely injured patients has increased the incidence of abdominal compartment syndrome (ACS) leading to the development of open abdomen strategy (OA). The open abdomen (OA) is a planned management strategy implemented in critically injured patients that need re-laparotomy to complete definitive surgery. Damage control surgery associated with damage control resuscitation and open abdomen resulted in eradicating the postoperative ACS in critically injured patients.

Additionally, OA implementation has been expanded to non-traumatic abdominal conditions. However, OA is a morbid condition with associated complications including principally intestinal fistula, abdominal fascia retraction, visceral adherences and ventral hernia. Temporarily abdomen closure is planned strategy for OA management aiming to minimize OA associated complications and increase abdominal fascia closure rate. Multiple temporarily abdomen closure techniques have been described, and vacuum assisted closure technique is commonly the most used technique with high rate of fascial closure and lower rate of complications.

Keywords: Abdominal fascia closure; Damage control surgery; Damage control resuscitation; Open abdomen

Abbreviations


Introduction

Performing definitive surgery in severely injured patients was reputed to be detrimental to outcomes [1]. So, delaying reconstruction and performing staged surgery with continuous resuscitation resulted in increasing patient survival with physiology derangement [2]. Despite the survival improvement, staged surgery or damage control surgery associated with abdominal fascial closure and large volume resuscitation has increased the incidence of abdominal compartment syndrome (ACS) leading to increased mortality in survived patients [3]. Very large fluid resuscitation and primary abdominal wall closure following damage control surgery have been recognized as predictor factors for ACS development [4,5]. Also, damage control resuscitation technique (DCR), based on fluid restriction and massive transfusion of blood products, has increasingly contributed to reducing ACS incidence [6-8].

The open abdomen (OA) strategy implemented with DCR following damage control surgery in high-risk patient of intra-abdominal hypertension (IAH) development has led to almost eradication of ACS in critically injured patients [6-8]. Therefore, DCS, DCR and OA form the modern care trauma in severely injured patients. In addition, DCS and OA approaches are being implemented in non-trauma condition including severe abdominal sepsis, repeated abdominal surgery and secondary ACS. The increasing prevalence of OA and associated morbidity has prompted to develop multiple techniques of temporarily abdominal closure (TAC). However, the ideal TAC method should contain the abdominal content, prevent abdominal cavity contamination, viscera desiccation, evisceration and visceral adherences, facilitate peritoneal fluid evacuation, allow easy access to the abdominal cavity, and prevent abdominal fascia retraction and recurrent ACS [9-11]. Resuscitation of patient with OA should be continued including restoration of normal physiology with judicious fluid management and introduction of early enteral nutrition support. So, the optimal goal of early OA management is to facilitate early closure (within one week) and prevent associated complications including failure of the primary fascial closure, intestinal fistula, abdominal sepsis and ventral hernia.

Definition of Open Abdomen

The open abdomen (OA) is defined as an abdomen with unapproximated fascial edges to prevent intra-abdominal hypertension (IAH) or abdominal compartment syndrome in patients who are subjected to repeat operation. The OA strategy is implemented in severe abdominal trauma following damage control surgery, severe abdominal sepsis, abdominal wall necrosis, abdominal compartment syndrome and acute mesenteric ischemia [12].
The OA leads to abdominal wall retraction with high risk of abdominal cavity infection, visceral adherences and intestinal fistula formation with the need for further abdominal wall reconstruction. These multiple conveniences have led to the development of the temporarily abdominal closure concept. Temporarily abdominal closure (TCA) is a planned surgical management strategy implemented in patients with OA. So, the abdominal wall is temporarily closed by using several methods (skin or artificial materials) in order to protect the abdominal organs, avoid peritoneal cavity infection and reduce abdominal fascia and skin retraction [12].

**Indication and Risk Factors of OA**

Early decision to perform damage control surgery (DCS) may decrease mortality [13]. So, surgical trauma team should rapidly make decision whether performing definitive surgery or staged surgery, sometimes upon entering the operating room. Damage control surgery approach includes bleeding control, contained abdominal contamination, and delayed reconstructive surgery allowing resuscitation to optimize patient conditions. When implementing DCS, abdominal fascia closure is often delayed resulting in open abdomen because of the need to perform repeated laparotomy. So, iterative laparotomy associated with abdominal wall closure increases the risk of abdominal compartment syndrome (ACS).

Open abdomen strategy can be applied in patients with severe trauma injury and traumatic shock who need repeated celiotomy to perform complete surgery after damage control surgery. Also, OA can be indicated in severe abdominal sepsis following pancreatic necrosis, gastrointestinal tract injury or fistula with planned relaparotomy [14,15]. Severe abdominal wall injury, intra-abdominal hypertension (IAH) or ACS with need for decompressive laparotomy, and patients at high risk for postoperative ACS, are also an indication for implementing OA approach [16-18].

While managing severe trauma with hemorrhagic shock, damage control surgery approach is often implemented in association with OA strategy because DCS and OA strategy have almost the same risk factors. These common risk factors include intraoperative predictors such as exsanguination requiring transfusion of 10 units of packed red blood cells (PRBC) [19], physiologic derangement as ascertained by biologic values, acidosis (pH<7.2), hypothermia (temperature<34 C), and coagulopathy (prothrombin time: 16) [20,21].

Also, prolonged operative procedure (>90 min), difficulties to make the appropriate decision for treatment and limited technical conditions are the risk factors for applying DCS and OA strategy. Preoperative predictors of DCS also include high severity injury score (ISS≥25) associated with severe hemorrhagic shock (diastolic pressure<70 mmHg), low Glasgow Coma Score (GCS), and hypothermia, and poor clotting function [21]. Therefore, any of these factors should prompt the surgeon to perform a staged surgery with OA or TA-Cin severely trauma patient undergoing open laparotomy. However, the surgical management strategy must be based on the dynamic response to resuscitation, and damage control strategy remains primordial in the management of shocked patients or those not responding to intensive resuscitation [22].

**Temporary Abdominal Closure Options**

Initially, skin or fascial closure was employed to enhance the packing effect used to control bleeding particularly in liver trauma; however, this resulted in increasing the ACS incidence leading to the limited use of this treatment method [4,23]. The increase in ACS incidence following damage control surgery with abdominal wall closure has led to the development of the open abdomen strategy. The temporarily abdominal closure aims to minimize the OA consequences. In addition, the surgical techniques have been increasingly refined focusing on stabilizing the abdominal compartment and allowing swift, convenient, removal and replacement of the temporary system. So, the ideal TAC would maintain abdominal viscera in homeostatic environment, limit peritoneal contamination, prevent bowel trauma, adherence formation and recurrent ACS, and also minimize skin and fascia trauma. Importantly, the TAC would prevent abdominal wall retraction and facilitate further primary fascial closure [9]. Indeed, the use of any temporary closure device should protect the underlying bowel and allowing easy access to the peritoneal cavity. Numerous TAC devices both commercial and self-designed are available for surgeons. Skin closure techniques, fascial closure techniques and negative pressure therapy are the available options to achieve TAC. There is no evidence-based preferable technique; however, the vacuum assisted closure technique is the most commonly used technique with high rate of abdominal fascial closure and lower complication rate. In addition, the combined use of fascial closure technique and vacuum assisted techniques was associated with a very high primary fascia closure (>86%).

**Skin closure techniques**

The skin closure techniques had their place in the early days of the TAC, including simple running suture of the skin, sequential towel clip closure, the silo technique, and the Bogota bag. Towel clip and suture closure of the skin are rapid and inexpensive; however, they are associated with increased risk of evisceration, skin necrosis, infection, and recurrent ACS (13% to 36%) that have led to their no use nowadays [24]. The silo technique and Bogota bag consists in suturing an inert non permeable barrier (sterile IV bag, bowel bag, Steri-Drape, Silastic cloth) to the skin or fascia in order to contain abdominal viscera. These inexperienced techniques with swift application allow some abdominal stabilization. However both techniques are prone to leakage, visceral adherences, evisceration and do not prevent abdominal fascial retraction [9,24]. The primary abdominal wall closure rates vary from 12 to 82% with ACS incidence ranging from 2.3 to 33.0% [25]. The enterocutaneous fistula (ECF) rates are lower varying from 0 to 14.4%.

**Fascial closure techniques**

The fascial closure technique (FCTs) is to suture grafting material the abdominal wall fascia, aiming to protect the abdominal viscera and allow progressive fascial approximation and closure [26,27]. Materials used include nonabsorbable meshes such as polypropylene mesh (Marlex mesh), Wittmann mesh, expanded polytetrafluoroethylene (ePTFE) mesh, polypropylene and ePTFE composite mesh, and absorbable meshes such as Vicryl or biological mesh.

When the non-absorbable mesh is used, the greater omentum should be placed to cover the bowel if at all possible in order to avoid direct contact between nonabsorbable material and bowel. The graft material should be redundant to prevent ACS development; it is gradually tightened by excising and suturing the central portion of the graft to facilitate fascial approximation in the postoperative stage [28-32]. Typically, the tightening is performed every 24-48 h until the
fascia is approximately 2-4 cm apart, and then the fascia is closed primarily [15,32,33].

The fascial closure techniques avoid the loss of domain resulting from wall retraction in OA. Achieving a reversible and tension-free TAC with facilitating reoperations is the greatest advantage of the FCTs, especially for patients with less opportunity of definitive closure of open abdomen within the first week [34,35]. The primary closure time has been extended to 50 days with FCTs [36]. However, these techniques are associated with high cost and require special equipment that is not available for all surgeons. Suturing the mesh graft to the abdominal fascia may increase the risk of fascia trauma and necrosis. In addition, FCTs do not prevent formation of adherences between anterior abdominal wall and the viscera, limiting abdominal wall mobilization for primary closure.

The most significant drawbacks of FCTs include lower rate of primary closure (18-38%), and high fistula rate (7-26%) with early use of absorbable material. Use of nonabsorbable material has improved primary closure rate (33 to 89%), however, fistula rate remained high (6-18%) [37,38]. Nowadays, the Wittmann Patch (WP) which is a nonabsorbable mesh using biological compatible artificial material, still has a popularity and is usually applied in clinical practice with overall good outcomes [38]. The primary closure rate for the WP method ranges from 78 to 100% with lower fistula rate (0-4.2%) [39,40].

**Negative-pressure therapy**

The negative pressure therapy has been used in the management of OA in 1995[41], and several systems have been described. Vacuum-assisted closure technique consists of covering the bowel by the omentum underlying the wound. Then tailored polyvinyl alcohol and gelatin sponge composite material is sutured to abdominal fascia providing more accommodation of the abdomen content and preventing visceral desiccation. Next, a biological membrane is set to seal the foam and wounds (3-4 cm over the edge of incision), and a negative pressure (45-60 mmHg) is applied by connecting the silicone tube to machine. So, the abdominal cavity is separated from outside environment preventing infection. The Vacuum-assisted closure is the most commonly used technique to manage OA with various choices including Abdominal Dressing System and ABThera System [30,42].

The abdominal dressing consists of using an inert plastic encased sponge, the perforated plastic interface covers the entire viscera, paracolic gutters (right and left) and the entire fascial defect, preventing viscera adherence to the overlying peritoneum, protecting bowel and allowing fluid drainage. A macroporous GranuFoam sponge as the middle layer is fixed to the fascia and subcutaneous tissue and must not be in contact with underlying viscera and should contain drains to provide suction. Finally, a bio-occlusive adhesive sheet (Ioban) fixed laterally to the flank skin, maintains the abdominal wall integrity facilitating change of patient position if necessary.

The ABThera system (figure 1) uses visceral protective layer covering the whole abdominal contents from pelvis to diaphragm and laterally the paracolic gutters, allowing prevention of visceral adhesion, and facilitating further abdominal wall mobilisation. The protected sponger the second layer can be placed in the pelvic space deep in the paracolic gutters resulting in facilitating effective evacuation of the peritoneal fluids. Finally an occlusive layer with GranuFoam and draining set is applied as previously described [43]. As illustrated in figure 1, the ABThera system allows protection of the abdominal cavity content and skin facilitating abdominal closure.

Various pressures with continuous or intermittent suction can be applied [35,44,45]. These vacuum-assisted closure systems prevent desiccation and mechanical damage of viscera with reducing fistula formation, avoid abdominal cavity contamination, reduce the abdominal domain loss with maintaining IAP and allowing evacuation of peritoneal fluids [46,47]. Also, continuous vacuum drainage is benefit to alleviating inflammation and edema, as well as facilitating wound healing.

The primary fascial closure and fistula rates using these systems were 33 to 100% (average 67%) and 0-15% (average 2.9%) respectively [10,39,44,48]. The fistula risk was increased with intra-abdominal sepsis, prolonged closure time and when primary closure was not possible [49]. The highest primary fascia closure rates (80%) were obtained when the vacuum assisted systems were used in combination with fascial tension technique. The combined use of fascial suture placement with sequential tightening or replacement to achieve fascial approximation, and vacuum assisted techniques was resulted in achieving a very high primary fascia closure (~90%) [35,44,45].

As reported, the negative pressure closure system is used earlier after the first operation, and FCT is often employed during the first re-exploration if closure is not anticipated in a timely fashion [9]. This sequence option reduces the ACS rates during the high risk period of active resuscitation and facilitates evacuating a large volume of peritoneal fluid.

The FCT increases the chances of primary closure during the subacute period. Uncomplicated patients have generally a high primary closure rate and closure can be achieved within 4-7 days regardless of TCA type used [10,50,51]. The abdominal closure time tends to be superior to one week, generally to 20-40 days with lower closure rate in patients with complicated and prolonged resuscitation efforts and hospital courses [35,45,51-55]. Several risk factors have been identified to predict prolonged or complicated course with decreased primary closure rate including prolonged OA time, multiple injuries with particularly colonic or duodenal injury, and active infection [9,49,51].
The infections (surgical site or blood stream infections) resulted in augmenting closure time and decreasing closure rate [56]. Also, conservative fluid resuscitation, less blood transfusion and negative fluid balance were associated with improved rate of primary closure [49,50,51,56].

Management of Patients with an Open Abdomen (Medical Treatment)

The resuscitation must be continued in the postoperative setting following DCS and OA strategy. Efforts should be focused on correcting tissue oxygen delivery, coagulopathy, hypothermia and providing an energy support within first 24 h [57]. As proved, the very large volume resuscitation with overload fluids increased the incidence of ACS and OA [48]. So, damage control resuscitation with crystalloid infusion restriction and early use of blood products has increasingly improved outcomes, reduced ACS incidence and increased early abdominal closure rate [49-51].

Additionally, recent study reports have showed a relationship between crystalloidal resuscitation or negative fluid balance and primary abdominal closure rates [23,52]. Intra-abdominal pressure (IAP) should be monitored in patients who received large-volume resuscitation for persistent hemodynamic instability or prolonged bleeding and in patients with OA secondary to ACS. Because IAH or ACS can occur or recur [53,54]. Increased IAP exceeding 20 mmHg should be monitored hourly, if any sign of organ dysfunction occurs, the TAC should be removed and replaced with a large dressing. Extending the initial incision should be considered if necessary [9]. The neuromuscular blockade has been used for early management of IAH and ACS and resulted in decreasing IAP, however, the IAP returned to baseline levels once the paralysis were off [53,54]. The scarce study results were controversial regarding the primary abdominal closure rate. However, a short course of neuromuscular block agents (NMBAs) as adjunct to negative pressure devices and methods may decrease fascial edge retraction [49,55]. The high rates of NMBAs associated complications and the poor results have limited the neuromuscular blockade use [56]. The benefits of early enteral nutrition in trauma or postoperative setting has clearly been highlighted and validated by the several published studies [57,58]. The OA results in significant protein loss (2g/day) making necessary the introduction of nutritional support [59]. Early nutrition is associated with increased primary abdominal closure and decrease of intestinal fistula, infection, ICU stay length and hospital costs [60-62]. The enteral feeding is highly privileged and recommended, and should be provided through enteral access via nasogastric or nasojejunal feeding tube. However, gastrosomy or jejunostomy tubes should be used with caution owing to the leak and fistula risks, and potential compromise of future abdominal closure options [63,64].

Conclusion

Damage control surgery combined with open abdomen strategy and damage control resuscitation has resulted in improvement of outcomes and almost eradication of postoperative ACS development in severely injured patients. However open abdomen is morbid condition and several techniques have been described to minimize the associated complications and increase abdominal fascia closure rate. The most commonly used technique is vacuum assisted closure technique with high rate of abdominal fascial closure and lower complication rate. Additionally, the combined use of fascial closure technique and vacuum assisted systems was resulted in achieving a very high primary fascia closure.

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