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REVIEW ARTICLE

Planned re-laparotomy and the need for optimization of physiology and immunology

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Abstract Planned re-laparotomy or damage control laparotomy (DCL), first described by Dr. Harlan Stone in 1983, has become a widely utilized technique in a broad range of patients and operative situations. Studies have validated the use of DCL by demonstrating decreased mortality and morbidity in trauma, general surgery and abdominal vascular catastrophes. Indications for planned re-laparotomy include severe physiologic derangements, coagulopathy, concern for bowel ischemia, and abdominal compartment syndrome. The immunology of DCL patients is not well described in humans, but promising animal studies suggest a benefit from the open abdomen (OA) and several human trials on this subject are currently underway. Optimal critical care of patients with OA's, including sedation, paralysis, nutrition, antimicrobial and fluid management strategies have been associated with improved closure rates and recovery.

Keywords Re-laparotomy · Damage control laparotomy · Open abdomen

Introduction

Damage control laparotomy (DCL) consists of three distinct stages, an abbreviated initial surgery with temporary abdominal closure (TAC); resuscitation and restoration of normal physiology, and definitive treatment and closure. The first abbreviated surgery should concentrate on control of hemorrhage and limitation of contamination followed by temporary closure [1]. The optimal TAC strategy should protect the bowel, evacuate fluid, provide rapid and easy access to the abdominal cavity, and allow for expansion of abdominal contents to prevent abdominal compartment syndrome (ACS) [3–5]. The second stage focuses on resuscitation, including judicious fluid administration, correction of coagulopathy, acidosis, and hypothermia as well as ongoing treatment of any active infections. Other critical care management may include sedation and paralysis, early enteral nutrition, and diuresis. The goal of the second stage of DCL is to facilitate rapid return to the operating room. Lastly, the third stage of DCL is definitive repair of injuries and abdominal wall closure. The third stage, re-laparotomy, should occur as soon as normal physiology has been restored. Damage control laparotomy has been associated with improved outcomes and decreased mortality in severely injured trauma patients [5–9], abdominal sepsis [7, 10–14], abdominal compartment syndrome [15–22], and vascular abdominal emergencies [23–25].

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Indications for DCL

Ideally, the decision to perform DCL should occur as early as possible, as studies have found an improved mortality to be associated with early decision making in both trauma and general surgery patients [26, 27]. Pre-operative predictors in trauma patients include penetrating torso, blunt abdominal, or severe pelvic trauma with hypotension (SBP < 90 mmHg); need for resuscitative thoracotomy; SBP < 60 mmHg upon arrival; hypothermia; inappropriate bradycardia; and pH of <7.2 [1, 28, 29]. Intraoperative indications include; medical bleeding, hypothermia, severe acidosis, transfusion of ≥10 units, or total fluid replacement >12L [5, 6]. Platelet count, PT, aPTT, and fibrinogen levels suggesting coagulopathy should also encourage conversion to DCL if available [29].

Patients undergoing decompressive laparotomy for ACS, and those general or vascular surgery patients felt to be at high risk for development of ACS including those requiring >15L of crystalloid or 10 Units of packed red cells, those with significant visceral edema, or with eleveated peak inspiratory pressure should undergo DCL/TAC [30, 31].

Planned re-laparotomy for serial debridements and evaluation of bowel viability is also indicated after embolic phenomenon or mesenteric venous occlusive disease and severe abdominal sepsis, especially following pancreatic necrosis [10–14, 16, 27, 32–35]. Ruptured abdominal aortic aneurysms also benefit from planned re-laparotomy and DCL with decreases in morbidity, mortality and colonic ischemia [23–25].

First stage: abbreviated laparotomy

Once a decision to perform DCL has been made, every effort should be made to make the initial operation as brief as possible in order to get the patient to the intensive care unit (ICU) for aggressive resuscitation. During the initial operation, wide exposure should be obtained rapidly, via re-opening of previous incisions, or a long vertical midline laparotomy incision in those without recent prior surgery. Once the abdomen has been opened all intra-abdominal fluid collections should be evacuated and all surgical bleeding and gross contamination should be rapidly controlled. Easily performed and rapidly deployed techniques such as stapled resection or primary repair of bowel injuries and primary repair, ligation, or shunting of vascular injuries should be utilized. Complicated anastomoses, patch repairs, or grafts should be avoided. Solid organ injuries should be addressed with repair, resection or placement of temporary packs as quickly as possible. If abdominal packing is necessary for hemorrhage control, care should be taken to avoid compression of the inferior vena cava which may cause deleterious hemodynamic and respiratory effects.

In cases of abdominal sepsis gross contamination should be controlled, all devitalized or frankly infected tissues should be debrided, and ischemic bowel should be resected. If a perforated bowel cannot be resected safely and quickly; diversion, exclusion or wide drainage should be performed. Complicated bowel anastomoses and reconstructions should be avoided.

Once hemorrhage and contamination have been controlled, a TAC should be placed. Options include the Bogota bag or silo technique, placement of mesh, and vacuum-assisted wound closure devices (VAWC). The Bogota bag involves suturing a sterile plastic sheet, to the fascial edges, and was invented by Dr. Oswaldo Borraez in 1984 [36]. This techniques is inexpensive and rapidly deployed. However, it is prone to leakage, does not prevent abdominal wall retraction, and is associated with rates of ACS ranging from 2.3 % to 33 %, and Enterocutaneous Fistulae (ECF) rates ranging from 0 % to 14.4 % [37]. Mesh closure is similar with suturing of vicryl mesh or artificial material, such as the Wittman Patch, to the fascial edges. Initially the graft material should be redundant to allow for visceral swelling reducing the risk of development of ACS [38–41]. These devices are well suited to long term control of the OA and allow for progressive abdominal closure; however, they can be associated with high risk of bowel injury and ECF formation [42]. Lastly VAWC devices cover the bowel with perforated plastic or silastic sheeting, followed by gauze, a towel or foam, which is then covered with an occlusive dressing and attached to suction. This technique allows for rapid re-exploration, evacuates fluid well, does not harm fascial edges, and associated ECF rates are low ranging from 0 % to 15 % [43–45].

Second stage: resuscitation and ICU care

Resuscitation

The goals of the second stage of DCL are restoration of physiology, early return to the operating room, and promotion of primary abdominal closure. The first part, resuscitation, is focused on correction of physiologic derangements, acidosis, oxygen debt, coagulopathy and hypothermia [1]. Hemodynamic derangements due to hypovolemic shock should be reversed as quickly as possible, ideally within the first 24 h, with volume resuscitation. [1, 46–49]. However, high volume crystalloids resuscitation can result in third spacing, anastomotic leaks, ACS and multi-organ failure [47, 50]. Accordingly, massive transfusion protocols (MTP) have been recommended as an alternative form of resuscitation for DCL patients [46, 47, 49, 51]. Massive transfusion protocols's advocate using blood transfusion earlier in resuscitation, using blood and blood products instead of crystalloid or colloid, and the infusion of red cells, plasma, and platelets in a 1:1:1 ratio. Evidence suggests that MTP's and the use of 1:1:1 transfusion ratios result in lower overall fluid requirements, blood utilization, and possibly improved mortality in patients with severe injury and physiological derangements, such as are encountered in DCL patients [51–53]. In addition, fluid resuscitation should be guided by dynamic parameters such as stroke volume variance or pulse pressure differentials and central venous or left atrial pressures. Judicious fluid management may decrease the incidence of ACS and promote early fascial closure [20, 53, 54]. This was supported in a recent study where restricted crystalloid fluid infusion (<20L) was found to be associated with improved primary closure rates [20, 54].

Diuretics have also been utilized anecdotally to promote primary closure, as it is thought that Lasix or mannitol may decrease bowel edema. However, while studies do demonstrate an association between net negative fluid balance and higher primary closure rates [20, 54–57], there is no convincing data to suggest the addition of diuretics improves the rate or time to closure [58].

In contrast, there is some evidence that the use of hypertonic fluid resuscitation in the immediate postoperative period may decrease time to primary closure and improve the primary closure rate among OA patients [59].

Sedation/analgesia/neuromuscular blockade

Experts agree that deep sedation may increase rates of primary closure among DCL patients, and there is also some evidence that epidural anesthesia may reduce intra-abdominal pressure in patients with ACS [3, 61]. Additionally, sedation and analgesia may be helpful in improving patient synchrony with mechanical ventilation particularly in DCL patients with acute lung injury or adult respiratory distress syndrome (ARDS) where higher levels of ventilator support are necessary [61]. Unfortunately, the optimal route, dose, or degree of narcotics and sedatives in patients with OA's are not clearly defined.

Neuromuscular blockade (NMB) has been effectively used as a treatment for early ACS [17, 62]. Because of this, it has been suggested that NMB may be used to prevent abdominal wall retraction and improve closure rates, however, evidence comparing NMB to sedation alone is equivocal [55, 63]. It should also be kept in mind that NMB's are associated with increased risks of infections, decubitis and device related ulcers, thromboembolic complications, and ICU neuromyopathy [64].

Enteral feeding

Early enteral nutrition is known to promote recovery of patients following severe injury, and has been clearly validated in numerous studies [65–67]. Patients with OA's, in particular, may benefit from early nutrition as their protein losses have been shown to be up to two grams daily. Early enteral nutrition can decrease the negative nitrogen balance [22]. While no randomized controlled trials exist, early enteral feeding has been associated with increased primary closure rates; decreased bowel edema, risks of ECF, infectious complications, ICU days, and hospital costs [68–71].

Antibiotic use

Appropriate prophylactic antibiotics should be administered preoperatively whenever possible as infection rates increase if given intra-operatively or postoperatively [72], and should be re-dosed intraoperatively if large resuscitations or significant fluid shifting is anticipated during the case [72–74]. Prophylactic antibiotics should not extend beyond 24 h in patients with OA even in the presence of hollow viscus injury [55, 75]. The exception to this rule is DCL performed for abdominal sepsis. In these cases broad spectrum antibiotics covering a wide range of skin and bowel flora should be started preoperatively and continued until intra-operative culture results are available then tapered according to sensitivities. Antibiotic duration should be determined by the primary abdominal pathology, in general 4–7 days as recommended by the Surgical Infection Society and Infectious Disease Society of America [61]. Alternatively antibiotics may be discontinued earlier when clinical signs of infection have resolved [3].

Immunology and pathophysiology

Peritoneal and abdominal injury from trauma or following surgical intervention stimulates mast cell degranulation, releasing histamine, kinins, leukotrienes, prostacyclines, and free radicals. These agents increase vascular and peritoneal permeability creating ascites rich in complement and coagulation factors [76, 77]. Injured surfaces also release tissue factor activating the coagulation cascade. Granulocytes and macrophages attracted to the injured peritoneal cavity then release IL-1, IL-6, TNF-α, IFN-γ. These cytokines are released into the systemic circulation causing fever, leukocytosis, MOF including ARDS, and mortality among trauma [78] and intra-abdominal sepsis patients [79–81]. Increased tissue permeability may also lead to bacterial translocation increasing risks of infection and further increasing the systemic inflammatory response [82].

There is some evidence from animal models of hemorrhagic shock that suggest the use of hypertonic saline solutions (HTS) rather than isotonic crystalloids may attenuate both the inflammatory response (TNF-α, IL-6) as well as organ dysfunction [83–86]. Similar anti-inflammatory effects have been seen in small human trials as well [86]. Hypertonic saline solutions may also reduce the risk of multi-organ failure, sepsis and mortality among patients requiring DCL [87, 88]. However, these benefits have not been consistently demonstrated among trauma patients in general [89–92].

Negative pressure dressings remove cytokines, matrix metalloproteinase, elastase, plasmin and thrombin when applied to wounds [93]. There is also evidence in animal models that suggests removal of these substances by negative pressure dressings may improve wound healing [93–98]. Animal models of DCL using VAWC's also suggest improved ascites removal compared to passive drainage systems, an associated reduction in systemic inflammatory markers (TNF-α, IL-6, IL-12, IL-1β), as well as decreased intestinal, lung, renal and hepatic injury on histopathology [76, 99, 100]. The impact of VAWC devices on mortality, organ dysfunction, primary closure rates, and abdominal wound healing in humans undergoing DCL may be beneficial [101] but has yet to be definitively proven [76, 100]. In an effort to answer these questions, there are several ongoing randomized controlled trial of VAWC devices in trauma and emergency general surgery patients undergoing DCL [76, 100].

Third stage: definitive surgery and closure

Timing of return to operating room

Initial return to the operating room should occur as soon as normal physiology has been restored and can vary from 6 h to 72 h from the time of the primary procedure [3]. The optimal time for pack removal is unclear, while it is important to leave the packs long enough to allow adequate tamponade and clot formation, if left too long the risk for abdominal infection and organ injury increases, particularly if packs are left more than 72 h [1]. Studies suggest that the ideal time for pack removal is likely between 24 h and 48 h of the first procedure [1, 102]. It would appear the majority of surgeons are aware of these risks as a survey from the Western Trauma Association found the majority of its members wait approximately 24 h for the first re-laparotomy [3]. Patients should also be taken back to the operating room if there is evidence of surgical bleeding, concern for missed or inadequately addressed injury. In cases of abdominal sepsis, planned re-laparotomy may have a slight trend toward increased survival over on-demand laparotomies particularly in the cases where optimal source control is not technically achievable at the time of the first operation. However, this may come at the expense of increased costs, number of operations, and lengths of ICU and hospital stay [10, 11, 27, 103].

Factors affecting primary closure

Once all injuries, infections, and debridements have been definitively addressed, then primary closure as quickly as possible should be the goal. Patients with OA appear to fall into a bimodal closure distribution. The first group is relatively uncomplicated and closure occurs early, primarily within 2–7 days, and rates of primary closure are very high [3, 56, 104, 105]. The second later peak has more complicated injuries, abdominal closure occurs quite late, and rates of primary closure among this group of patients is lower than the first group [3, 56, 104, 105]. Factors affecting primary closure rates in both trauma and non-trauma patients include the presence of ECF, surgical site and blood stream infections, higher early fluid balance and initial tissue hypoperfusion [57, 104, 105]. Additionally, the longer the duration of OA, the lower the chances of eventual primary closure, with primary closure being very unlikely after eight days in trauma and 12 days in non-trauma patients [56, 105]. The factors associated with failure to achieve primary closure again highlight the importance of rapid resuscitation and optimization of physiology and immunology during the second stage of damage control surgery.

Conclusion

The indications for DCL have expanded from trauma to include vascular and general surgery patients and those with abdominal sepsis. Damage control laparotomy has been associated with decreased morbidity, multi-organ failure and mortality among trauma, vascular, acute care surgery, and ACS patients. The conversion to damage control should occur early in the management of these patients in order to obtain the maximal survival benefit. Surgeons have various commercial and self-made options for TAC following DCL. The VAWC or Barker vacuum pack methods have clear advantages following the first stage laparotomy including ease of application and removal. Vacuum-assisted wound closure devices result in high rates of primary closure and may reduce peritoneal and systemic inflammatory markers with possible improvements in multi-organ dysfunction and mortality.

Immediate post-operative management should be directed at restoration of normal physiology, this may include MTP's and hypertonic saline. While judicious fluid management, lower initial fluid requirements, or early negative fluid balance are associated with higher rates of primary closure, the addition of diuretics has not resulted in similar benefits. Intensive care unit management should include early enteral nutrition and may include sedation and neuromuscular blockade, but should not include prolonged courses of antibiotics outside of patients operated on for abdominal sepsis.

Conflict of interest None.

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