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RESEARCH ARTICLE

DYNAMIC WOUND CLOSURE SYSTEM AND OPEN ABDOMEN, SAFETY AND EFFICACY

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ABSTRACT

Introduction: Damage-control surgery is abbreviated surgery performed to control a patient's life-threatening illness. It minimizes the time during which the patient is exposed to coagulopathic stimuli, hypothermia and acidosis in the operating room in favour of returning the patient to the intensive care unit as expeditiously as possible for a full resuscitation. **Aim:** Evaluation of efficacy and safety of dynamic wound closure system in open abdomen **Methods:** Between March 2018 and March 2019, 12 patients with severe peritonitis and abdominal trauma were stabilized by laparotomy and the developed open abdomen was treated by dynamic wound closure (ABRA SYSTEM) after a variable period of ICU admission with strict following of the protocol of damage control surgery (DCS). **Results:** The mean duration ICU admission before ABRA application was 5 days. The mean duration of ABRA application was 15days. The average width of the abdominal defect was 15 cm. The average length of defect was 20 cm. Delayed primary abdominal closure was accomplished in 8 patients without further surgery. Incisional hernia with a small abdominal defect developed in 2 patients. Skin graft was applied over wide defect in 2 patients. **Conclusion:** Abdominal re-approximation by dynamic wound closure system is safe and effective, however it is very pain full and needs more analgesic support.

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INTRODUCTION

Damage-control surgery is abbreviated surgery performed to control a patient's life-threatening illness. It minimizes the time during which the patient is exposed to coagulopathic stimuli, hypothermia and acidosis in the operating room in favour of returning the patient to the intensive care unit as expeditiously as possible for a full resuscitation. It is typically performed for treatment of trauma, abdominal sepsis and abdominal compartment syndrome. Bowel and retroperitoneal edema resulting from hypo perfusion and resuscitative efforts frequently prevent reapproximation of the abdominal fascia. The patient is returned to the operating room 24–48 hours later for definitive treatment of the injuries should he or she survive (Scott, 2005). Definitive abdominal closure may not be possible for several days or weeks, until the patient has stabilized. Damage-control laparotomy has increased the number of patients surviving to require treatment for an open abdomen. Temporary abdominal wall closure can be achieved by placing an absorbable mesh or plastic visceral retainer and packing the resultant wound with gauze with or without retention sutures. The fascia then retracts laterally, and loss of abdominal domain begins.

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This may permanently prevent fascial closure and require treatment through a planned ventral hernia repair in which the exposed bowel, optionally covered with absorbable mesh, is allowed to develop a confluent layer of granulation tissue. After about 2 weeks, the abdomen becomes "frozen" from multiple adhesions between viscera, the remaining abdominal wall and the granulating surface. Future abdominal surgery is more complicated, with increased morbidity and mortality. The granulation tissue is later skin-grafted, and definitive repair of the resultant hernia is performed in 9–12 months, if technically feasible with techniques such as skin stretching and components of separation flaps (Hultman, 2005; Howdieshell *et al*., 2004; Flum, 2003). A ventral hernia is a suboptimal result. In the state of Washington, a study followed 10 822 patients who had surgery for incisional hernias over 13 years.7 The rates for reoccurring hernias were 12.3% at 5 years and 23.1% at 13 years. An increase in the use of mesh from 34.1% in 1987 to 65.5% in 1999 did not affect cumulative recurrence rates. Similar results are reported elsewhere (V'ant Riet, 2002). Patients often have permanent disabling abdominal wall defects that cause postural imbalance, gastrointestinal (GI) symptoms and loss of adequate diaphragmal support for ventilation. These defects demonstrate the importance of achieving complete fascial closure in the treatment of open abdominal wounds (Wang, 2019).

A new FDA listed system (ABRA by Canica) has been introduced using a progressive tension system as a novel approach to the management of open abdomen. ABRA provides a dynamic reduction of full thickness, severely retracted midline abdominal defects with the goal of maintaining or restoring the primary closure option. This subdermal method uses button anchors and elastomer to gradually pull the wound margins together. Tension can be set and adjusted according to the desired outcome; to stabilize a retracted wound, reduce the wound, close the wound or prevent wound dehiscence (Attachment 1: Company brochure) (Ribeiro Junior, 2016). Currently there is only one published case report of the success of this device. We hope to be the first center to prospectively report a series of patients with open abdomen managed with the new ABRA system. The objectives of this study were to evaluate the Canica ABRA® dynamic fascial closure system and, in particular, to determine the efficacy and safety of dynamic wound closure system in open abdomen.

PATIENTS AND METHODS

Our study included12 patients with severe peritonitis and abdominal trauma who were stabilized by laparotomy between March 2018 to March 2019 (fig. 1and 2).

Fig. 1. Retracted linea alba and Rectus abdominus

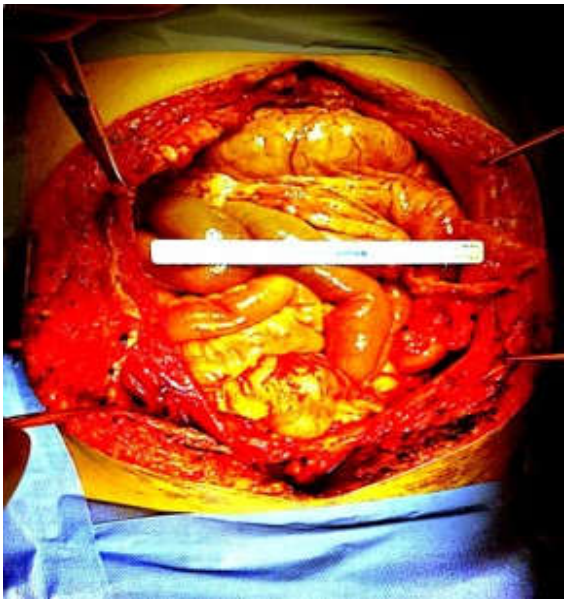

Fig. 2. Width of open abdomen

Patients had the following criteria

Inclusion Criteria

- ages of 18 and 60
- Patients deemed not a candidate for primary fascial closure at the second laparotomy.
- Exclusion Criteria:
- High risk for imminent death, as determined by the attending surgeon and PI
- Pre-existing large ventral hernia
- Known Crohn's disease
- Pregnancy

We applied the ABRA® system according to the manufacturer's instructions. An elastomer is inserted through a stab incision starting about 5 cm back from the wound edge and across the defect, preferably passing below the fascia and above a mesh or other visceral retainer. It exits an equal distance back from the wound edge on the contralateral side. These elastomers are placed about 3 cm apart along the wound length, which is as close as the padding of the button anchors will permit. Button anchors are placed, and the elastomers are connected and tensioned to about twice their tension-free length (290 g) (Fig. 3).

Fig. 3. ABRA system application

Fig. 4. Manual approximation

To prevent the elastomer tearing medially through the abdominal wall, an adhesive button tail is attached to the anchor and fixed to the skin (Fig. 4). Dressing changes are performed as per standard practices. The system is inspected daily, and elastomer tension is adjusted as needed to maintain a constant force of 290 g. In case of skin tearing or ulceration, tension is reduced and additional padding is placed under the anchor. Primary suture closure was performed when it was possible to approximate the fascial edges (Fig. 5).

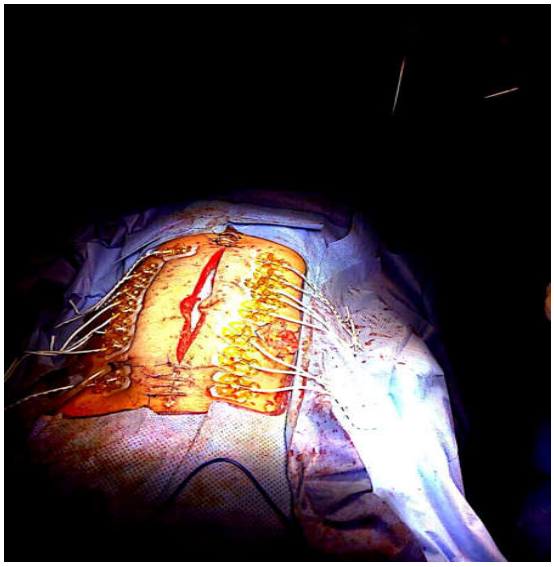

Fig. 5. Final wound gap

Split-thickness skin grafting was employed when no further fascial approximation could be achieved by medial traction. Patients were selected for application of this system when the consulting surgeon was of the opinion that traditional wound management approaches would not allow fascial reapproximation and that no other options existed apart from a planned ventral hernia approach. Cases were not consecutive and were chosen when a participating surgeon was consulted and when the closure equipment was available. We measured the original length and width of the open abdomens by ruler when the system was first applied and again when the system was removed; length and width were defined as 0 if the fascia was completely reapproximated. To calculate wound area, we assumed the wound to be rectangular and multiplied the length by the width. Hernia occurrence after system removal was determined clinically. The presence of herniation and the need for a skin graft were determined by a hospital chart review conducted in November 2005. This study received approval from our hospital's research ethics board.

Statistical analysis: Results were analyzed using SPSS (ver. 25.0; IBM, Chicago, IL, USA). Quantitative data was displayed in the form of mean ± standard deviation (SD). Qualitative data was demonstrated through figures of frequency and percentage. Qualitative data were expressed as percentage. For quantitative data, comparison between two groups was performed using independent sample t-test. All reported p-values were two-sided. P-value< 0.05 was considered statistically significant.

RESULTS

In table 1, patients are listed according to primary pathology: trauma(*n*=4), Perforated diverticulitis (*n*=2), hernia (*n*=2), anastomotic leak post-traumatic (n=2) and gangarene(*n*=2). Of thepatients, 66.6% were men. Patients have mean age of 35± 5.97. In table 2, the average width of the abdominal defect was 15± 4.23 cm. The average length of defect was 20± 1.92 cm. In table 3, mean duration of wound closure was14.5± 1.7 days, mean duration of ICU admission was 10± 1.5 days and mean duration of ABRA application was 15± 1.6 days. Also, 2 patients had pain, 2 had ugly scar, 8 had delayed closure and 2 had incisional hernia. In table 4, there were statistical significant differences between patients with delayed closure and immediate closure as regard age, width of the defect, length of the defect, duration of wound closure, duration of ICU admission, duration of ABRA application and complications.

DISCUSSION

Hernia repair after failed abdominal closure frequently requires skin grafting, can cause accidental bowel damage and can fail, leading to recurrent herniation (Olona, 2014). Although primary closure of the abdominal wall is not the immediate goal in damage-control laparotomy, dynamic traction allows for stretching and relaxation of the abdomen with each respiration in a physiological fashion while preventing further lateral retraction of the abdominal muscles and fascia. Several mechanisms support the concept of dynamic closure. Direct fascial stretching and expansion works through the principles of biological and mechanical creep (Desai, 2016). Mechanical stress upregulates tissue growth. Breburda and colleagues (Breburda, 2001) have shown that intermittent alternating tension and pressure microstimulation of growth plate fractures in bone stimulates chondrocyte proliferation. Langevin and colleagues (Langevin, 2005) demonstrated that subjecting mouse tissue to stretching increases fibroblast cell body perimeter and cross-sectional area. Fibroblast morphology changed from dentritic to sheetlike under tissue stretching, and the changes could be diminished by subjecting the stretched cells to the antimitotics colchicine and cytochalasin D. This suggests that cell biosynthesis adapts to a proliferative phenotype as a result of stretching (Coccolini, 2017).

Using complementary DNA microchip array technology, Kessler and colleagues (Kessler, 2001) showed that 60 known genes were induced in mechanically stressed fibroblasts and 64 known genes were induced in a mechanically relaxed system. They defined induction as a 3-fold or greater change above baseline and concluded that mechanically stressed fibroblasts assumed a synthetic phenotype that down regulated the production of proteases and inflammatory mediators. The expression of connective tissue growth is up regulated in cells exposed to mechanical stress. It is also known that fibroblasts respond differently to growth factor stimulation depending on whether they are tensioned or untensioned, with the former acquiring a proliferative or biosynthetic phenotype as opposed to a quiescent phenotype in the latter (Grinnell, 2003). Changes also occur at the endothelial level, where shear stress enhances endothelial wound closure (Coccolini, 2019). Consequently, dynamic wound closure may exert benefits through multiple mechanisms at the cellular level. This dynamic wound closure system presents an alternative to the conventional late management of open abdomens. In this series, we report successful delayed primary closure in 66.6% of cases with mean duration of ABRA application of 15± 1.3 days. A similar issue was examined by Miller and colleagues (Miller, 2002), who suggested that vacuum-assisted fascial closure could be used to achieve closure up to 1 month after

Table 1. General characteristics of study population

Clinical characteristics	(n=12)
Width of the defect$_{(cm)}$	15± 4.23
Length of the defect$_{(cm)}$	20± 1.92
Wound exudate	
Purulent	6(50%)
Fecal	4(33.3%)
Serosanguinous	2(16.7%)

Table 2. Clinical data of the patients

Characteristics	(n=12)
Age $_{(years)}$	35.0± 5.97 (22-50)
Sex	8(66.7%)
Male	4(33.3%)
Female	
Causes	
Trauma	4(33.2%)
Perforated diverticulitis	2(16.7%)
Hernia	2(16.7%)
Anastomotic leak post-traumatic	2(16.7%)
Gangarene	2(16.7%)

Table 3. Post-operative data

Post-operative data	(n=12)
Duration of wound closure $_{(days)}$	14.5± 1.7
Duration of ICU admission $_{(days)}$	10± 1.5
Duration of ABRA application$_{(days)}$	15± 1.6
Complications	
Pain	2(16.7%)
Ugly scar	4(33.3%)
Delayed closure	8(66.6%)
Incisional hernia	2(16.7%)
Type of closure	
Skin only	8(66.6%)
Fascial graft	2(16.7%)
Incisional hernia repair	2(16.7%)

Table 4. Comparison of characteristics in patients with successful and patients with delayed closures

	Immediate Closure (n=4)	Delayed closure (n=8)	p-value
Age $_{(years)}$	35.0± 6.18	41.0± 3.42	0.005*
Width of the defect$_{(cm)}$	12± 3.09	15± 4.27	0.012*
Length of the defect$_{(cm)}$	18± 1.22	20± 1.07	0.033*
Duration of wound closure$_{(days)}$	11.9± 0.91	15± 1.5	0.001*
Duration of ICU admission$_{(days)}$	8.2± 0.79	10± 1.3	0.042*
Duration of ABRA application	12.4± 1.11	15± 1.3	0.041*
Complications			
Pain	1(8.3%)	1(8.3%)	
Ugly scar	0(0%)	4(33.3%)	<0.001*
Incisional hernia	0(0%)	2(16.7%)	

initial laparotomy. Steenvoorde (Steenvoorde *et al*., 2006) demonstrated that use of negative pressure as a single method in the treatment of open abdomens failed because of retraction of the abdominal muscles. The dynamic wound closure system has 2 components: silicone elastomers and silicone-padded button anchors. The elastomers are applied to penetrate all abdominal layers, or as many as possible, depending on the mobility of the wound edge. Where abundant granulation tissue overgrowth was present when the system was placed several days after initial laparotomy, safe exposure of fascial flaps on either side of the wound was hindered. In such cases, the elastomer was placed through skin and subcutaneous tissues only. Before the elastomers were placed, an absorbable mesh was placed to cover underlying bowel. Usually, a single piece of vicryl mesh was used. However, in patients with considerable widening of the abdominal defect, 2 pieces were stacked to prolong mesh integrity.

In our study, skin only closure in 8(66.6%), fascial graft in 2(16.7%) and incisional in 2(16.7%). The mean adimission in ICU before ABRA was 5 days. Our results were more favourable than those in a study by Howdieshell and colleagues **(**Howdieshell *et al*., 2004**)**, who treated 71 surviving patients with open abdomens with the tension-free insertion of a silicone sheet. Of these, 24 (34%) achieved delayed primary fascial closure during the initial admission, and 34 (66%) required visceral skin grafting and readmission for closure.

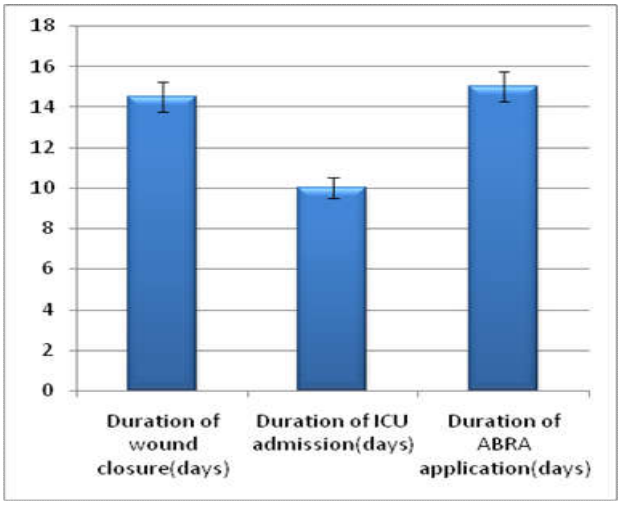

Figure 5. Post-operative clinical data

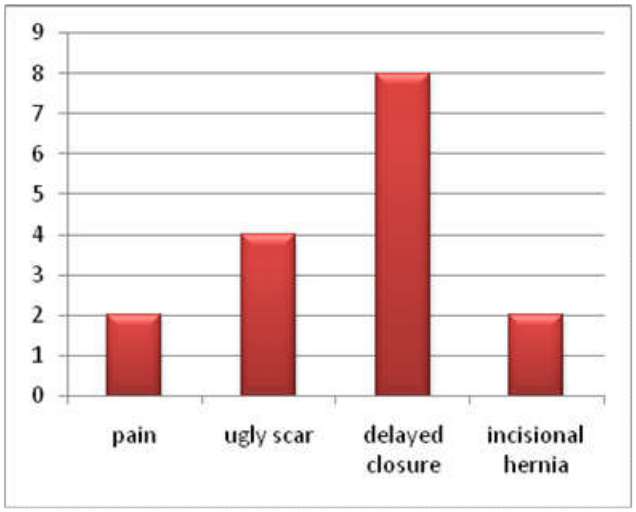

Figure 6. Post-operative complications

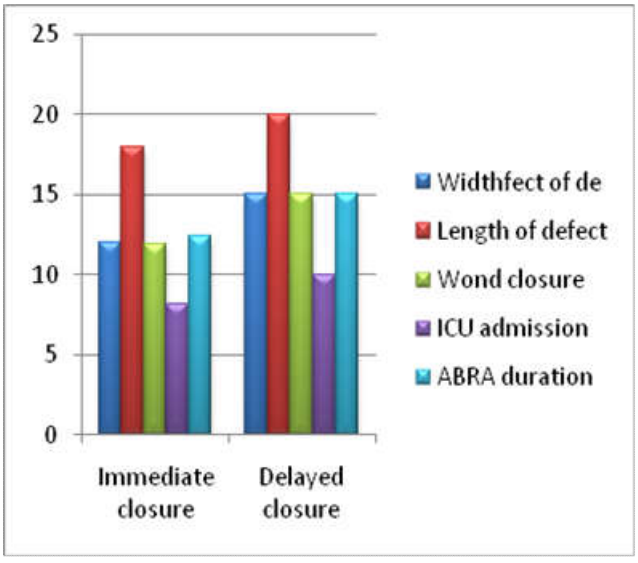

Figure 7. Comparison of characteristics in patients with successful and patients with delayed closures.

A key difference between these studies and the present case series is our extremely late initiation of treatment, when significant adhesions and fascial retraction presented a much more difficult abdomen to close (Sriussadaporn *et al*., 2003).

To our knowledge, these results are the best ever reported for the closure of open abdomens when treatment is started 5 days after the initial laparotomy. Hernias were found in 16.7% of our cases. Although the true rate was possibly higher, it compares well to the alternative of a 100% hernia rate in patients treated with a "planned ventral hernia epair" approach (Rasilainen, 2012; Bradley, 2013). In our study, 16.7% patients had pain, 16.7% had ugly scar, and 66.6 % had delayed closure. In *Reimer et al.* (2008) study dynamic wound closure likely reduced the need for future reconstructive surgery and spared patients from its related morbidity. Two enterocutaneous fistulae (9%) occurred. This common complication has beenreported to occur in 4%–25% of patients (Bradley, 2003), and its incidence is considered lower with the use of absorbable mesh. Hence, we would recommend that a single or double layer of absorbable mesh be placed to function as a visceral retainer in patients where it may remain permanently in situ. In this study, there were statistical significant differences between patients with delayed closure and immediate closure as regard age, width of the defect, length of the defect, duration of wound closure, duration of ICU admission, duration of ABRA application and complications.

In Reimer et al. (2008) study, advanced age, higher SAPS II probability of dying and GI disease were proportionally more common in the group with failed closure, and these factors may therefore be predictive of poor outcome. The delay between when the abdomen was considered open and the application of the closure system was not associated with successful closure in this small series. A more timely application of the system at the first laparotomy that results in the open abdomen might yield faster and higher closure rates. Arguably, there would be less scar tissue present to impede fascial reapproximation. Survival outcomes and long-term follow-up of patients were not performed. Both of these could be assessed in future studies to elucidate whether a relation exists between fascial closure technique and survival or delayed hernia recurrence.

Conclusion

The presented data, although limited, suggest that this dynamic wound closure system shows promising results in the late management of open abdominal wounds. Future controlled studies are needed to determine the best indications for dynamic wound closure and the best timing for the application of the closure system.

Compliance with ethical standards: The authors have declared no conflicts of interest

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