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ORIGINAL ARTICLE

Use of dynamic wound closure system in conjunction with vacuum-assisted closure therapy in delayed closure of open abdomen

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Abstract
Aim Definitive abdominal closure may not be possible for several days or weeks after laparotomy in damage-control surgery, abdominal compartment syndrome and intraabdominal sepsis, until the patient has stabilized. Vacuum-assisted closure (VAC therapy®, KCI, San Antonio, TX, USA) and abdominal re-approximation anchor system (ABRA, Canica, Almonte, Ontario, Canada) are novel techniques in delayed closure of open abdomen. Our aim is to present the use of these strategies in the management of 7 patients with open abdomen.
Methods Between August 2010 and December 2011, 7 patients with severe peritonitis were stabilized by laparotomy and treated with either ABRA system or ABRA system in conjunction with VAC dressing. VAC dressing applied to 4 patients initially and followed by ABRA. ABRA was applied alone to remaining 3 patients. Demographic data and patient characteristics, timing of VAC dressing and ABRA system were recorded. ICU and hospital stay and development of incisional hernia were also recorded. Stage of open abdomen, width of abdominal defect, extent to damage to fascia, and pressure sores were staged.
Results The mean duration with VAC dressing before ABRA application was 18 days. The mean duration of ABRA application was 53 days. The average width of the abdominal defect was 18 cm. The average length of defect was 20.8 cm. Delayed primary abdominal closure was accomplished in 6 patients without further surgery. Incisional hernia with a small abdominal defect developed in 2 patients.
Conclusion Abdominal re-approximation anchor system and VAC dressing can be used separately or in conjunction with each other for closure of delayed open abdomen successfully.

Keywords Severe sepsis · Fascia · Abdomen

Introduction

Open abdomen is very important in the management of patients with abdominal compartment syndrome, damage-control surgery and abdominal sepsis [1, 2]. It has been proven to decrease mortality and early postoperative complications. However, delayed morbidity and need for further surgical procedures remain uncertain. Several novel methods and devices have been improved and used to increase the chance of definitive closure of open abdomen. When closure of the open abdomen is not possible, various sequelae-like large abdominal wall defects, enterocutaneous fistulas and ventral hernias are not uncommon [2, 3].

Vacuum-assisted closure (VAC therapy, KCI, San Antonio, TX, USA) is a novel strategy based on the use of defined and controlled negative pressure over a polyurethane or

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polyvinyl sponge placed in the wound. It evacuates the inflammatory exudate. This technique can be used in the treatment of traumatic wounds, pressure ulcers, diabetic foot ulcers, infected sternotomy wounds and complex pleural empyema [3–5].

Abdominal re-approximation anchor system (ABRA, Canica, Almonte, Ontario, Canada) is another method, designed for the delayed closure of open abdomen and various wounds [6, 7]. It is based on continuous dynamic tension to achieve re-approximation of the fascial edges of the abdominal wall by transfacial elastomers [8].

We aimed to present the use of VAC in conjunction with ABRA in management of open abdomen of 7 patients with generalized sepsis due to peritonitis.

Materials and methods

Population characteristics

We present our experience with VAC therapy and ABRA system used in 7 septic patients with open abdomen in our hospital between "August 2010 and December 2011". The causes for the need for open abdomen treatment and type of the primary surgery of each patient were shown in Table 1.

ICU care consideration

Before any kind of abdominal closure method should be applied, hemodynamic stability and control of the sepsis was established in ICU after the first operation. General supportive measures were established such as antibiotic treatment, mechanical ventilation, repeated lavage, fluid therapy and nutritional support. Enteral nutrition was started to all patients as early as possible after intestinal continuity has been established. Glutamine supplementation was provided to account for losses from the open abdomen. Intraabdominal pressure was recorded before the first operation and was not routinely monitored. The classification for open abdomens according to Björck was noted before the application of the VAC dressing and ABRA system: grade 1A, clean OA without adherence between bowel and abdominal wall or fixity of the abdominal wall; grade 1B, contaminated OA without adherence/fixity; grade 2A, clean OA developing adherence/fixity; grade 2B, contaminated OA developing adherence/fixity; grade 3, OA complicated by fistula formation and grade 4, frozen OA with adherent/fixed bowel, unable to close surgically, with or without fistula (Table 2) [9].

Duration from laparotomy to first application VAC dressing and ABRA system, width of the abdominal defect (cm), extent to the damage to the fascia were scored as a 3 point scale: 1, undamaged; 2, damaged 3, severely damaged were recorded [8]. Length of ICU and hospital stay and occurence of incisional hernia were recorded during clinic follow-up. Pressure sores developing due to application of ABRA were staged according to Barczak et al. [10]. Before application of VAC dressing and ABRA, the wound was debrided and adhesions to the viscera were carefully dissected. VAC dressing was applied to 4 patients with more purulent material within the abdomen, when the purulent drainage decreased; ABRA was added to the treatment protocol. ABRA was applied singly to remaining 3 patients with less purulent material within the abdomen (Fig. 1).

Technique of VAC dressing

A fenestrated polyethylene sheet was applied over the viscera under the fascial edges and facilitated fluid drainage into the foam and prevented adherence (Fig. 2). The

Table 1 Patient characteristics

	Etiology	Operation	Age	Sex	BMI	Length of ICU stay (days)	Length of hospital stay (days)
1	Colon perforation (colon ca)	Hartmann procedure	43	M	30.0	32	63
2	Perforation of spleen abscess	Splenectomy lavage	78	M	29.0	28	45
3	Evisceration recurrent incisional hernia repair	Debridman + lavage	56	F	46.8	3	38
4	Leakage of duodenal stump 7 days after gastric perforation repair	Repair with omental patch + lavage	54	F	36.6	29	29
5	Leakage of anastomosis after low anterior resection (Rectum ca)	Primary repair + loop ileostomy	75	M	18.2	30	50
6	Perforation of superinfected pelvic hydatid cyst	Partial cystectomy + debridman + lavage	85	F	16.0	23	39
7	Colon perforation after sigmoid volvulus	Resection + anastomosis + loop ileostomy	68	M	22.1	21	47

Table 2 Patient characteristics

	Apache II score	Intraabdominal pressure (cm H_2O)	Björck Class	Length of the defect	Width of fascial defect	Fascia score	Pressure sores
1	20	28	2B	25	16	2	2
2	23	26	2B	23	17	1	1
3	20	–	2A	20	19	2	2
4	26	26	3B	24	25	3	–
5	23	25	2B	21	17	2	1
6	25	21	2B	17	14	2	2
7	19	28	2A	16	18	1	2

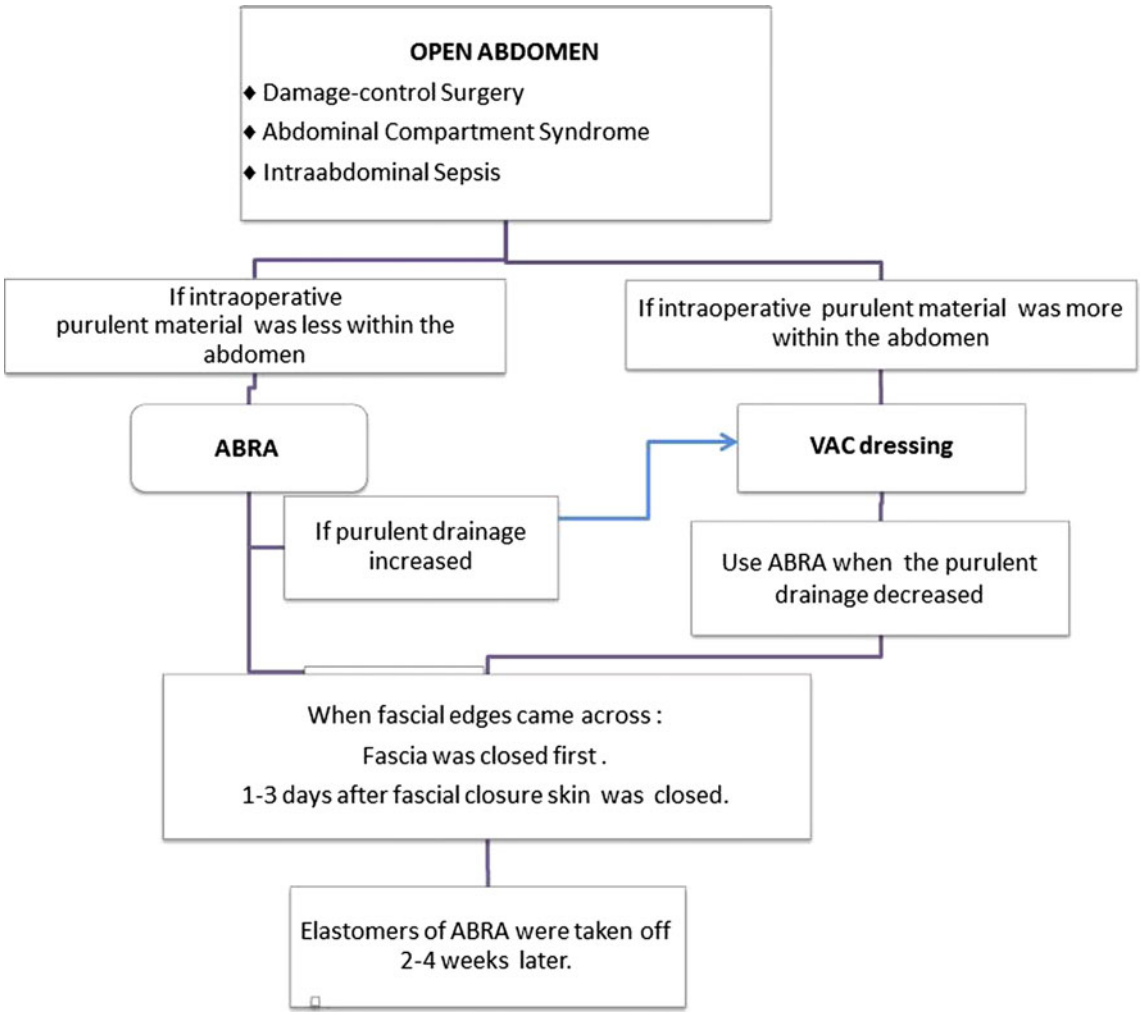

Fig. 1 Study flow chart

sponge was placed over the polyethylene sheet. Drape was inserted over the sponge approximately 10 cm from the wound margin (Fig. 3). The fascia was gradually pulled over the viscera by pulling the edges of the wound toward the midline. The traction on the edges of the abdominal wall was provided by the suction applied to dressing. It prevented fascial retraction by creating constant medial tension on the fascia. This pressure was adjusted at −125 mmHg which was the critical pressure to stimulate cell reproduction and to maximize the negative tissue expansion. The dressing was changed every 3–5 days depending on purulent secretion or increased infection. VAC dressing was initially applied in the operating theater and changes were performed at bed site.

Fig. 2 Application of a fenestrated polyethylene sheet over the open abdomen

Fig. 3 The sponge was placed over the polyethylene sheet and drape was inserted over the sponge approximately 10 cm from the wound margin

Technique of ABRA system

It was performed in the operating theater. After the wound was surgically debrided (Fig. 4), elastomers were inserted through the full thickness of the abdominal wall approximately 5 cm from the wound margin (Fig. 5). The elastomers were aligned about 3–5 cm apart across the open abdomen and fixed to the button anchors at the insertion site. A perforated silicone sheet was inserted between the abdominal wall and contents to prevent adhesions during the whole process. The silicone sheet was tucked under the elastomers and into the wound gutters in patients with inadequate granulation tissue formation; hence, VAC dressing was not applied to these patients. The black bars on the elastomer provide a visual indication of tension. Initial tension should be set at approximately a 1.5× stretch length of the calibration marks. The optimal tension was adjusted by stretching the elastomers and readjusted throughout the treatment. Abdominal wall was massaged to mobilize and reshape the abdominal wall at bedside. By this maneuver, wound margins advanced toward midline. As soon as the wound margins came across, fascial closure with PDS 1/0 absorbable sutures was performed in the

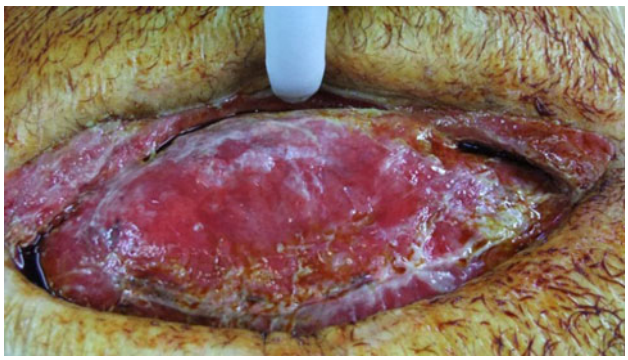

Fig. 4 Surgical debridement of the wound before ABRA application

operating room. Skin closure was performed 1–3 days after the fascial closure if there is no any infection or leakage at the wound site. Application of ABRA system was based on the clinical judgement of the surgeon. The final step consisted of readjustment of ABRA system after fascial and skin closure, approximately 1–2 weeks after the closure of fascia, if there is no any infection or leakage at wound site, and then the tension of ABRA was decreased step by step and approximately 2–4 weeks after this, the pads of ABRA were removed one by one.

Results

Patients' characteristics (etiology of open abdomen, type of operation, duration of ICU and hospital stay) and demographic values were summarized in Table 1. The mean Apache scores of the patients at the time of primary laparotomies were 22.3 (range 19–26) (Table 2). Intraabdominal pressure measured was 23.6 cm H_2O on average (range 18–28). The average length of ICU stay was 23.7 days (range 3–30) and the total length of hospital stay was 44.4 days (range 29–63). According to the abdominal scoring system by Björck et al. [9], 2 patients are classified as grade 2A, 4 patients are classified as grade 2B and 1 patients as grade 3 (Table 2). The average fascial width was 18 cm (range 14–25 cm). The average length of the defect was 20.8 cm (range 16–25 cm). Fascia condition at the time of ABRA application was staged as a 3-point scale: 1, undamaged; 2, damaged and 3, severely damaged (Table 2). Pressure sores at anchor sites were encountered in all patients, 2 of them were grade I and 4 of them were grade II (Table 2). All the pressure sores were healed well with appropriate elastomer tensioning and wound care, since in most cases, pressure sores were superficial. Duration from laparotomy to first application VAC dressing was 13 days. The mean duration with VAC dressing before ABRA application was 18 days (range 15–21) and the mean duration of ABRA application was 53 days

Fig. 5 Insertion of elastomers through the full thickness of the abdominal wall approximately 5 cm from the wound margin

Fig. 6 One month after delayed abdominal closure with ABRA

(range 40–62) (Table 3). One of the seven patients died two days after the application of ABRA because of pulmonary embolism. The duration of ABRA application to this patient was excluded. The average width of the abdominal defect was 18 cm (range 14–25) at ABRA application. Primary abdominal closure was accomplished in all patients (Fig. 6). But incisional hernia with small fascial defects (1 with 3×4 cm, 1 with 3×3 cm) developed only in 2 patients. We did not use mesh in any of the patients. After closure, there was no wound infection. Fistula formation did not occured in any of the patients.

Discussion

Patients with open abdomen are critically ill and septic. Success and timing of surgery, treatment of intraabdominal infection, prevention of multiorgan failure and control of sepsis are the priorities of the patients with open abdomen. Mortality and morbidity rate is too high because of the abdominal wall integrity degradation, fluid and protein loss, heat loss, wound contamination and intraabdominal sepsis in the patients with open abdomen. They have a high risk of developing major complications such as multiple organ failure (30–40 %), enterocutaneous fistula (2–25 %), intraabdominal abscess (83 %) and abdominal wall hernia (around 25 %). Patients with open abdomen might develop large and debilitating ventral hernias requiring complex repair surgery [11].

Several temporary closure techniques have been used to manage the open abdomen such as skin approximation, Bogota bag, absorbable mesh, Marlex with zipper, vacuum pack closure and VAC with various success [12]. All of these alternatives have a problem of inability to obtain primary fascial closure beyond 7–10 days. The viscera may adhere to the anterior abdominal wall, and development of fascial retraction necessitates a future major abdominal operation [13].

Development of ventral hernias remains as one of the major problems encountered in the delayed closure of open abdomen. Verdam et al. stated in their patient population that 4 of the infected 16 open abdomen developed a ventral hernia after delayed closure [11]. Reimer et al. demonstrated in their study that ventral hernia developed in 6 of 23 patients. Four of these 6 hernias developed in patients with an open abdomen with gastrointestinal sepsis [8]. In our case series, 2 patients developed small incisional hernia. ABRA system applied on average 19th day and could not be inserted at a distance of 5 cm from the medial margin optimally, since fascia could not be separated completely from the viscera in these 2 patients. Timing of approximation is an important factor for successful closure

Table 3 Timing and duration of application of VAC therapy and ABRA system

	1st VAC therapy after first laparotomy	Duration of VAC therapy (days)	1st ABRA application (after first laparotomy)	Duration of ABRA application
1	11	21	26	53
2	–	–	10	40
3	15	20	31	55
4	14	15	25	4
5	12	16	21	62
6	–	–	7	55
7	–	–	13	54

of open abdomen. Early application is preferable to prevent development of fascial retraction and to reduce the time for closure. We applied our approximation system on average 19th day, compared with 12 days in previously mentioned study [8]. Mentula stated that highest fascial closure rates have been obtained with VAC systems and continuous fascial traction systems [14]. Verdam et al. stated that primary abdominal closure was accomplished in 14 of 16 patients (88 %) without use of mesh [11]. Mesh was not used at all in our patients as well.

Abdominal re-approximation anchor system has been used specifically for delayed closure of open abdomen of mainly non-septic origin [8]. In patients, VAC dressing and ABRA system have been used together, dynamic traction was provided by ABRA, and drainage of abdominal exudate and reduction in edema were ensured by VAC dressing. Jacobs et al. have indicated that VAC device with −125 mmHg continuous negative pressure showed accelerated wound closure rates and increased pro-angiogenic growth factor production in rats [15]. The cyclic application of negative pressure increases the rate of cell division and formation of granulation tissue [16]. ABRA system provides a dynamic traction adjusted continuously and allows expansion and retraction without damaging fascia.

Vacuum-assisted closure dressing and ABRA are valuable tools for the management of the patients with open abdomen. They can easily be readjusted at bedside without need of general anesthesia. But if necessary, a sedative or analgesic agent should be given.

It would be of value to study the combined use of VAC dressing and ABRA system in a prospective randomized study. We proposed an algorithm for management of delayed closure of open abdomen in different clinical pictures (Fig. 1).

In conclusion, effectiveness of both techniques and ease of application make ABRA system and VAC dressing attractive options for restoration of abdominal integrity in patients with open abdomen. ABRA system can be used in conjunction with VAC dressing for management of delayed closure of open abdomen.

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