Observational Study

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# A preliminary prospective study of patients who underwent vacuum-assisted and mesh-mediated fascial traction techniques for open abdomen management with negative fluid therapy

## An observational study

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**Abstract**

It is unclear whether strategies targeting negative fluid balance are associated with facilitated early fascial closure. The present study investigated the effects of fluid removal therapy on early facial closure of open abdomen patients.

A prospective study was conducted in patients who underwent open abdomen management with vacuum-assisted and mesh-mediated fascial traction technique. Therapeutic diuresis with torasemide was applied to cause negative fluid balance in the treatment group. The study and follow-up periods were 7 and 180 days, respectively. The observational indices included the intra-abdominal pressure, the number of days to closure, the type of closure, the septic complications, the duration of ventilation support, the duration of initial hospital stay, and the duration of intensive care unit (ICU) stay.

A total of 27 patients were divided into the treatment (16 patients) and control (11 patients) groups. The median intra-abdominal pressure (IAP) of the patients of the control and the treatment groups was significantly lower at day 7 compared with the baseline value ($P < .0001$). IAP was lower in the treatment group compared with that noted in the control group, following day 4 of the fluid removal therapy ($P < .05$). The percentage weight loss in the treatment group was between 4.80% and 10.88%. The early closure rates were significantly higher in the treatment group compared with those in the control group (75.0% vs 18.2%, $P = .0063$).

Fluid removal therapy combined with vacuum-assisted and mesh-mediated fascial traction provided a high early fascial closure rate for open abdomen patients.

**Abbreviations:** ACS = abdominal compartment syndrome, ALT = alanine aminotransferase, APACHE = Acute Physiology and Chronic Health Evaluation, BMI = body mass index, BWC = body weight change, CHD = coronary heart disease, CKD = chronic kidney disease, CRRT = continuous renal replacement therapy, IAH = intra-abdominal hypertension, IAP = intra-abdominal pressure, ICU = intensive care unit, LOS = length of hospital stay, OA = open abdomen, SOC = standard of care, TAC = temporary abdominal closure, VAWCM = vacuum-assisted wound closure with mesh-mediated fascial traction.

**Keywords:** early fascial closure, fluid removal therapy, open abdomen, renal replacement therapy, torasemide, vacuum-assisted and mesh-mediated fascial traction

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*All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. This article does not contain any studies with animals performed by any of the authors.*

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## 1. Introduction

Management of open abdomen (OA) remains a formidable problem to the surgeon, although it has been an effective treatment of abdominal catastrophes in both trauma and general surgery. Ogilvie introduced the term OA in the early 1940s.[1] The abdomen was left open for 1 to 4 days, following the initial operation.[1] An initial comparison of the septic abdomen to any other septic wound was conducted and the abdominal wall was closed at a later stage.[1] Subsequent studies by Duff and Moffat[2] described the use of OA as a last resort strategy to treat the development of intra-abdominal sepsis when all other treatment options had failed and the abdomen could no longer be closed. The latter study concluded that OA could be used as an alternative technique given a mortality rate of 39%,[2] while other studies have supported the use of OA as a technique that achieves adequate drainage of the septic abdominal cavity and decreases the mortality rates from >50% to approximately 38%.[3–5]

The most common indications for OA include trauma, abdominal sepsis, severe acute pancreatitis, and intra-abdominal hypertension comorbidities that are associated with the prevention of the development of an abdominal compartment syndrome (ACS).[6–9] OA utilizes a multidisciplinary approach that requires the close cooperation between the surgeons and the intensive care unit (ICU) team in order to achieve survival improvement and morbidity reduction. It has been suggested that a therapy that focuses on early opening and early closure is the key in ACS.[10] A combination of medical and surgical therapies that include negative pressure wound therapy and dynamic closure has been proposed in the management of the open abdomen surgery, in place of the "old" conception to "close the wound at any cost."[10]

Severe abdominal infection is indicated in patients undergoing open abdomen surgery in case of an ineffective laparotomy source control.[11,12] In addition, the open management enables a repeated check of the operation, during the repeated debridement of the nonviable tissue and during the requirement of peritoneal toilet, and effective drainage. The increased prevalence of OA has prompted the development of temporary abdominal closure (TAC) that serves as a barrier for the aforementioned complications. The ideal TAC techniques are able to prevent evisceration and contamination, allow easy access to the abdominal cavity and prevent fistula formation.[13] The assisting temporary abdominal closure techniques have evolved from packing, Bogota bags, mesh, to vacuum-assisted closure.[14–18] In a previous study conducted in our center, the combination of vacuum-assisted wound closure with mesh-mediated fascial traction (VAWCM) was used in order to achieve primary facial closure.[19] The study demonstrated that patients with fluid-related weight gain of >10% had a lower primary facial closure rate compared with those that exhibited a weight gain <10%.[19] This suggested that fluid volume overload negatively influences delayed primary facial closure using the VAWCM technique.[19] It is recommended that definitive fascial closure within the initial hospitalization may avoid the risks associated with OA and planned ventral hernias compared with staged management. The intensive care management throughout the OA is important to the surgical success of primary fascial closure. As regards critically ill patients undergoing OA treatment, the fluid resuscitation may lead to volume overload and increase the risks of ACS, pulmonary edema, and acute respiratory distress syndrome.[20] Several authors have reported that an increased or positive fluid balance has been associated with third space fluid accumulation and negatively influenced primary facial closure.[21] Despite such studies, it remains unclear whether strategies that target negative fluid balance following the initial resuscitation of critically ill patients can be associated with improved fascial closure.

Acute renal failure was recently found to be one of the independent risk factors of the failure to achieve primary fascial closure in OA patients.[22] Therapeutic diuresis using furosemide in the presence and/or absence of continuous renal replacement therapy (CRRT) is a medical treatment option that aims to enforce negative fluid balances and improve the abdominal wall compliance. The application of furosemide in the treatment of open abdomen fascial closure has not been extensively studied. Patients that received furosemide did not demonstrate an association with primary fascial closure in a sample size of 139 subjects, 25 of which revived furosemide treatment.[23] Furosemide may remove excess volume; however, forced diuresis with an furosemide is not associated with an increased rate of primary closure following damage control laparotomy.[23] With regard to renal replacement therapy the use of furosemide has been applied notably in heart transplant recipients with volume overload.[24] The present study aimed to investigate the effects of fluid removal in the achievement of early fascial closure compared with OA patients treated with sole standard of care (SOC).

## 2. Material and methods

### 2.1. Study design and population

This preliminary prospective study was carried out in the Department of Surgery, Jinling Hospital, Nanjing, China, from January 2013 to December 2015. It was approved by the Institutional Review Board Ethics Committee at Jinling Hospital and was conducted in accordance with the Declaration of Helsinki. Prior to the participation, written informed consent was obtained from each subject.

Subjects were assigned to either the treatment group or the control group according to the choice selected by the patients and/or their relatives. The treatment group was provided SOC along with fluid removal therapy, whereas the control group was provided SOC alone within 7 days following the day of enrollment. Following the treatment period, patients who failed to achieve fascial closure were further evaluated in order to examine the cause of open abdomen. The unclosed abdominal fasciae would either develop a planned ventral hernia or were subjected to partial fascial closure based on the patient conditions and the physicians discretion. Subsequently, the patients were followed-up for at least 180 days following closure of abdomens. The primary endpoint was the closure rates during the follow-up period. The secondary endpoint was the duration of OA, length of hospital stay, and ICU stay.

The inclusion criteria of this study were as follows: age >18 years; acceptance to participate to the study; patients who achieved hemodynamic stabilization following decompression laparotomy and with VAWCM technique application; patients that experienced positive fluid balance that required to be reversed. The exclusion criteria were abdominal wall hernia before OA treatment; anticipated OA treatment lasting <7 days; presence of fistulas; and death prior to abdominal closure.

### 2.2. Definitions

Intra-abdominal pressure (IAP), intra-abdominal hypertension (IAH), and abdominal compartment syndrome (ACS) were defined according to the World Society of the Abdominal Compartment Syndrome consensus.[25] IAP is the steady-state pressure concealed within the abdominal cavity and it should be measured at the end and during the expiration in the supine position with the transducer zeroed at the level of the midaxillary line. IAP should be monitored daily on the morning during the entire study period (10 AM) following enrollment of the patients. IAH is defined by a sustained or repeated pathological elevation in IAP of ≥12 mmHg. ACS is defined as an intra-abdominal pressure exceeding 20 mmHg and organ dysfunction.

Early fascial closure is defined as a reapproximated closure of abdominal fascia within the period of 2 to 3 weeks following an open abdomen. Delayed abdominal closure, administrated with absorbable or non-absorbable synthetic grafts and organic meshes, is an alternative reconstructive operation for the unclosed abdomen. This closure is typically completed 6 to 12 months or longer following an open abdomen.[17] Planned ventral hernia was defined as an open abdominal wound that is allowed to granulate and is covered with a skin graft prior to the patient discharge with the intention to perform definitive repair within 6 to 12 months. The habitual bodyweight was defined as the latest measured bodyweight reported by the patient or his relatives. The body weight change (BWC) was calculated as bodyweight prior to the initiation of OA treatment minus the habitual bodyweight. The standard of care conducted at our institution ensured that patients were weighed during OA treatment daily. The fluid intake included blood products, intravenous fluids and flushes, medications, and all forms of nutritional support. The fluid output included urine output, drains, blood loss, nasogastric tube output, stool volume, and wound drainage.[26]

### 2.3. Treatment protocol

SOC was applied to support all patients that included fluid/electrolyte balance, bowel rest, nutritional replacement, wound care, and TAC.[27] Antibacterial therapy was applied in patients with signs of systemic sepsis or inflammation with pain.[27] Adequate suction drainage with normal saline dripping at the same time was provided if needed.

The open abdomens were all applied to VAWCM techniques for primary facial closure, regarding the patients included in the present study. The principle of VAWCM as a TAC technique has been described previously.[19] In brief, a sterile non-adhesive plastic sheet was placed intra-abdominally to cover the viscera, while an oval-shaped polypropylene mesh (Prolene; Ethicon, Johnson & Johnson, Somerville, NJ) was sutured to the fascial edges with a running 0 monofilament suture. The moist gauze dressings covered the plastic sheet and protected the fascia and subcutaneous tissue. Two silicone drain tubes, one for instillation and one for suction, were placed in caudally through the skin over the gauze. The suction catheter of the sump drain was attached to an aspiration pump with continuous topical negative pressure of 100 to 150 mmHg. Persistent instillation by normal saline (150–300 mL/h) was carried out via the instillation catheter simultaneously. The drains were covered with a layer of dry laparotomy pads and the wound was sealed with adhesive plastic dressings. This TAC system was changed every 2 to 3 days with debridement as required and the possibility of abdomen closure was evaluated. If possible, the abdominal wall was closed. Alternatively, the mesh was cut in the midline and tightened by suturing in the midline with a running 0 monofilament suture, keeping the viscera from protruding and putting considerable tension on the abdominal wall. Abdominal fascial closure followed by skin closure or split skin grafting could be considered when 3 to 5 cm of separation of the fascial edges remained with weak tension. The delayed primary fascial closure referred to the ability to achieve fascial closure during the initial hospital stay.

The study period was set at 7 days following enrollment. In the treatment group, the fluid removal therapy aiming for negative daily fluid balances, was provided once a day during the study period. The human albumin solution (20% Solution, Baxter, Austria) was first administered with an intravenous infusion of 30 g/d. Then the torasemide was injected with an intravenous loading dose of 20 mg (20 mg, Nanjing Hichi Pharmaceutical Co. Ltd., China). For anuric patients, CRRT was initiated with an ultrafiltration rate in order to achieve neutral to negative daily fluid balances. Patients in the control group did not receive fluid removal therapy.

### 2.4. Data collection

For each enrolled patient, all of the following data were collected: age, sex, body mass index (BMI), comorbidity, etiologies contributing to the OA, primary indications for OA, Acute Physiology and Chronic Health Evaluation (APACHE II) scores, and IAP. During OA treatment, the daily flow charts were reviewed and 24 hours total fluid intake and output were recorded for each patient. The time and methods required for abdominal fascia closure were also collected. Venous blood for all laboratory tests was drawn between 5 AM and 6 AM. The laboratory values including white blood cell counts, red blood cell counts, hematocrit, alanine aminotransferase, aspartate transaminase, total bilirubin, albumin, and serum creatinine were calculated within 2 hours following blood collection.

### 2.5. Statistical analysis

Continuous variables are presented as medians and inter quartile range, while categorical variables are presented as percentages. The chi-square test or the Fisher exact test was used for qualitative variables. The differences between groups were tested with the Mann–Whitney $U$ test for nonparametric data. Paired data were analyzed with the Wilcoxon rank sum test. A two-sided $P$ value of $<.05$ was considered statistically significant. Statistical analysis was performed with SPSS version 17.0 (SPSS, Chicago, IL).

## 3. Results

### 3.1. Patient characteristics

During the period of January 2013 to December 2015, a total of 66 patients underwent abdominal open therapy, and 27 patients were enrolled in the present study. Patients were excluded due to the presence of enteroatmospheric fistulas (n=18), anticipated OA treatment of <7 days (n=16), pre-existent abdominal wall hernia prior to OA treatment (n=2), and/or death prior to abdominal closure (n=3). A total of 19 men (70.4%) and 8 women (29.6%) of the patients that met the inclusion criteria

**Table 1**

**Patient characteristics before open abdomen.**

| Variables | Treatment group (n=16) | Control group (n=11) | *P* value |
|---|---|---|---|
| Demographics | | | |
| Age, mean (SD) | 41.0 (12.68) | 35.7 (10.33) | >.05 |
| Gender (M:F) | 12:4 | 7:4 | >.05 |
| BMI | 26.0 (2.49) | 25.2 (2.14) | >.05 |
| APACHE II score | 26 (6.9) | 26 (6.7) | >.05 |
| IAP at day 0 | 22.7 (3.49) | 21.7 (3.10) | >.05 |
| Baseline laboratory values, mean (SD) | | | |
| ALT | 29 (20) | 30 (16) | >.05 |
| Albumin | 41 (7) | 40 (11) | >.05 |
| Serum creatinine | 73 (21) | 80 (14) | >.05 |
| Co-morbidities, n (%) | | | |
| Diabetes | 4 (25.0) | 2 (18.2) | >.05 |
| CHD | 1 (6.3) | 1 (9.1) | >.05 |
| CKD | 1 (6.3) | 1 (9.1) | >.05 |
| Etiopathogenisis, n (%) | | | |
| Peritonitis | 8 (50.0) | 5 (45.5) | >.05 |
| Hemorrhage | 6 (37.5) | 4 (36.4) | >.05 |
| Trauma | 2 (12.5) | 2 (18.1) | >.05 |

ALT=alanine aminotransferase, APACHE=Acute Physiology and Chronic Health Evaluation, BMI=body mass index, CHD=coronary heart disease, CKD=chronic kidney disease, IAP=intra-abdominal pressure.

exhibited a mean age of 39±11.6 years (Table 1). A total of 16 patients in the treatment group received fluid removal therapy, while 11 patients in the control group received standard care alone. There were no significant differences between the 2 groups as regards the baseline characteristics of the patients ($P > .05$). As regards patients in the treatment group, 11 received CRRT treatment with a mean therapy duration of 14.6±4.39 days.

The main disease etiologies contributing to the OA were diffuse peritonitis (13, 48.2%), peritoneal cavity hemorrhage (10, 37.0%), and severe trauma (4, 14.8%). The main indications for OA treatment were: documented intra-abdominal hypertension and/or abdominal compartment syndrome (16, 59.3%), planned relaparotomy for assessment of bowel viability (6, 22.2%), and diffuse peritonitis (5, 18.5%).

### *3.2. Effects of open abdomen treatment and fluid removal on IAP*

The median IAP before OA treatment was 21.4 mmHg (range, 17.9–28.7 mmHg) in 27 patients. Following initiation of OA treatment, it decreased significantly with a median value of 19.1 mmHg (range, 15.2–25.1 mmHg) ($P = .0298$). In addition, the continuous monitoring indicated that the IAP kept decreasing daily and the median IAP was 9.3 mmHg at day 7 (range, 7.7–13.9 mmHg), which was significantly lower compared with the baseline value ($P < .0001$). In contrast to this observation there were no significant differences between treatment group and control group on IAP following OA therapy until day 5. Following day 4, the fluid removal therapy reduced IAP markedly in the treatment group compared with the corresponding value in the control group ($P < .05$) (Fig. 1A).

### *3.3. Effects of fluid removal on bodyweight and bowel edema*

Daily fluid input did not exhibit significant differences between patients in the treatment group and the control group ($P > .05$) (Fig. 1B). In the presence of negative fluid therapy, the mean overall BWC in the treatment group was –5.6 kg (range, –3.7 to –9.2 kg), representing a mean percent BWC of –7.41% (range, –4.80% to –10.88%), although a general trend was observed as

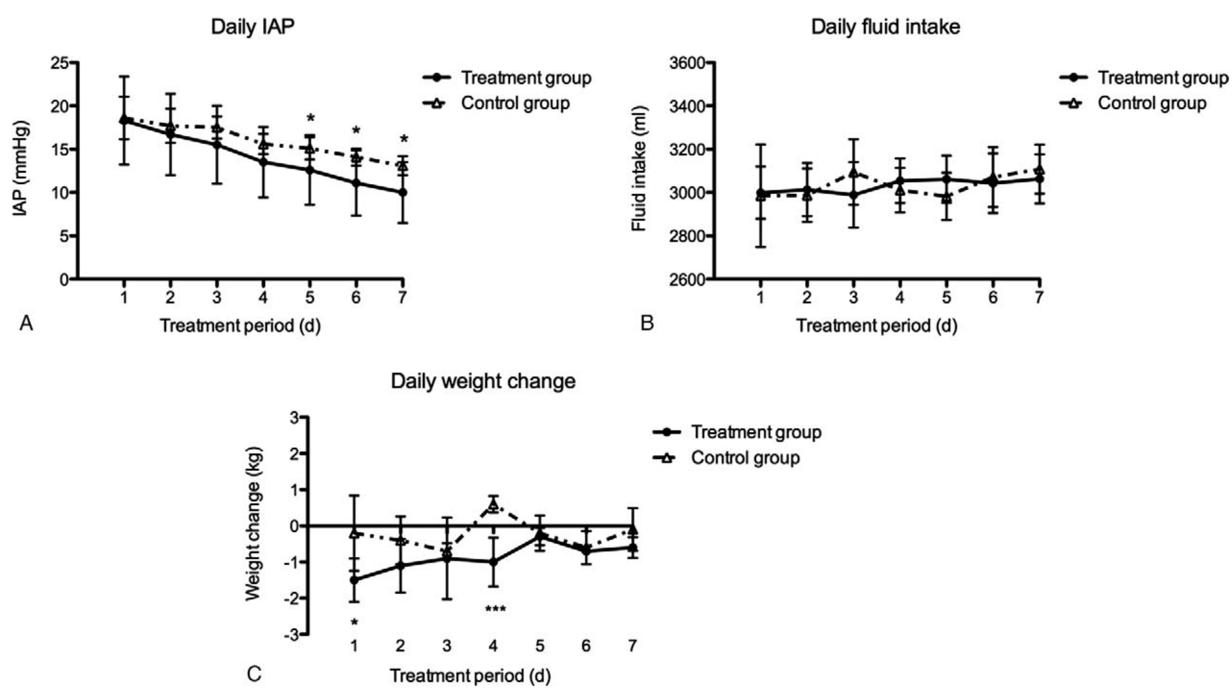


Figure 1. Daily IAP, fluid intake, and body weight change of all patients during the 7-day treatment period. A, IAP; B, Fluid intake; C, Body weight change. *$P < .05$, ***$P < .005$.

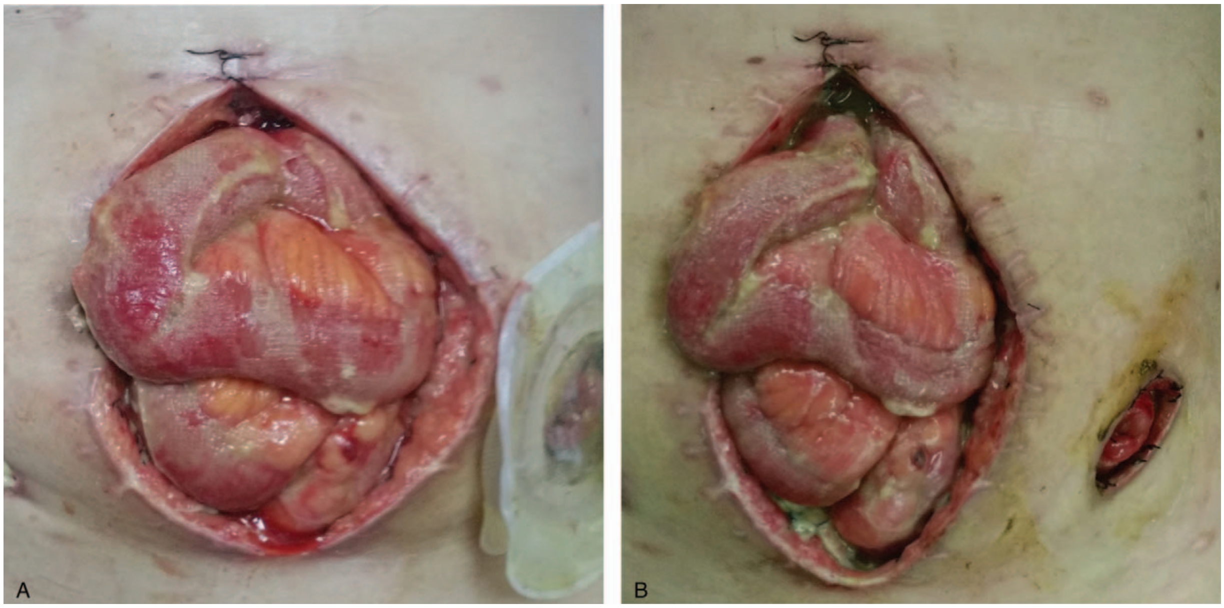


**Figure 2.** The fluid removal therapy reduces bowel oedema. A, Open abdomen when enrolled; B, open abdomen received the fluid removal treatment.

regards the rate of descent got smaller and smaller, and the weight decreased the most at Day 1. The overall BWC for patients that did not undergo fluid removal therapy during the study period, was –1.5 ± 0.41 kg, which was significantly lower than that noted in the treatment group ($P = .0016$). The percentage of BWC ranged from –0.42% to –2.96% (Fig. 1C). Among the 15 patients, 9 patients (60%) exhibited weight loss <5% and 6 patients (40%) had a weight loss of ≥5%. There were significantly more patients in the treatment group that experienced weight loss of >5% (85.7% vs 0%, $P = .0014$). The fluid removal therapy markedly reduced bowel edema and ultimately facilitated the abdominal closure (Fig. 2).

### 3.4. Outcomes

No patients died during the follow-up period. The early fascial closure was completed in 14 (51.9%) of the 27 patients, with 12 (85.7%) in the treatment group, and 2 (14.3%) in the control group (Table 2). The closure rates were significantly higher in the treatment group compared with the corresponding rates in the control group (75.0% vs 18.2%, $P = .0063$). The early fascial closure in the subjects that achieved negative fluid volume balance required a mean duration of 6 ± 0.5 days. The reasons for failure of primary closure in the 2 groups were the frozen abdomen formation (n = 6), the enteroatmospheric fistula formation (n = 5), and the abdominal wall defects (n = 2). The aforementioned patients either developed a planned ventral hernia or had a partial fascial closure. All of the patients experienced component separation and abdominal wall reconstruction, and had their abdomens successfully closed. As regards the patients devoid of primary fascial closure, definite surgery of abdominal wall reconstruction was achieved at 49 ± 23.8 day in the control group, and at 23 ± 17.0 day in the treatment group. The duration of OA in patients who received fluid removal therapy was significantly lower compared with that in the control group ([40 ± 28.0] days vs [11 ± 10.7] days, $P = .0299$). In contrast to the latter observation, there were no significant differences between the 2 groups as regards the initial hospital stay and ICU stay ($P > .05$).

**Table 2**

**Outcomes.**

| Variables | Treatment group (n = 16) | Control group (n = 11) | *P* value |
|---|---|---|---|
| Days to closure, mean (SD) | 11 (10.7) | 40 (28.0) | .0299 |
| Type of closure, n (%) | | | .0063 |
| Primary | 12 (75.0) | 2 (18.2) | |
| Definite | 4 (25.0) | 9 (81.8) | |
| Septic complications, n (%) | 2 (12.5) | 1 (9.1) | >.05 |
| Ventilator days, mean (SD) | 6.7 (0.97) | 11.0 (1.54) | .0366 |
| ICU LOS, mean (SD) | 41 (16.9) | 37 (7.7) | >.05 |
| Initial LOS, mean (SD) | 78 (38.8) | 68 (9.4) | >.05 |

LOS = length of hospital stay.

## 4. Discussion

In the present study, the achievement of negative fluid balance facilitated early fascial closure in the OA patients who received VAWCM treatment. When the fluid removal therapy was applied to the patients, the mean overall BWC in the treatment group was significantly higher compared with that in the control group during the 7-day study period. The early fascial closure rates were considerably greater in the treatment group compared with the corresponding closure rates noted in the control group (75.0% vs 18.2%). It has been previously suggested that early fascial closure should be considered the preferred option of treatment, in terms of clinical advantages compared with a delayed approach of treatment.[28] A total of 62% out of a sample size of 3125 patients successfully achieved early fascial closure and the latter treatment significantly reduced mortality compared with the delayed abdominal closure.[28] In addition, the mean interval duration in days that was required for definitive closure was significantly lower in the early fascial closure groups compared with the delayed closure groups.[28] The present study advances further to provide evidence regarding the contribution of the negative fluid balances in the efficacy of early fascial closure treatment for OA.

The management of OA has been accepted as one of the most important treatment in critically ill patients. In the present study, a clear decrease of IAP was noted following immediate opening of the abdomen. The latter decreased significantly from $22.3 \pm 3.22$ mmHg prior to OA treatment to $19.5 \pm 2.47$ mmHg following initiation of OA treatment ($P = .0298$). The open abdomen status is associated with risks of derangement of fluid and electrolyte balance, systemic inflammatory cascade, formation of gastrointestinal fistula, adhesions, and infection.[29–31] The main goal is to close the abdomen as quickly as clinically feasible during the management process. The traditional method of fascial defects closure is a planned ventral hernia that allows granulation of the wounds and is followed by application of a split-thickness skin graft. Planned ventral hernias, however, are also associated with multiple clinically risks and an increased cost of care. In this regard, it is recommended that all appropriate efforts should be made to attempt definitive facial closure within the initial hospitalization.

A variety of TAC techniques exist that consist of skin closure techniques, fascial closure techniques, and vacuum-assisted closure and are available for the closure of the open abdomen.[32] VAC is the most efficient technique compared with the Bogota bag and Barker techniques because it reduces the tension of the boarders of the lesion and removes the stagnant fluids and debri.[33] Recently, the use of mesh-attached to abdominal fascia has been reported to be comparable in efficacy with vacuum-assisted closure.[34] However, the combination of the 2 latter techniques enhances greatly the overall fascial closure rates compared with either treatment alone and/or other temporary abdominal closure treatments.[35] In a study conducted by Willms et al[8] a considerably low rate of mortality was reported from the combination of the 2 techniques. In the present study, the mesh-mediated fascial closure along with vacuum-assisted closure techniques was combined to promote early primary closure. The combination of the 2 TAC techniques worked in a synergistic way to facilitate closure of the open abdomens. VAWCM treatment was found to be safe and could provide a high fascial closure rate.[36] However, it may lead to high incidence of fistulas. Diaz et al[11] reported that approximately 75% OA patients experienced fistula formation in the absence of a non-adherent barrier or omentum placed over the bowel for protection. In our center, the gauze was placed between bowels and mesh to avoid damages and adhesions. Despite these precautions 2 enteroatmospheric fistulas occurred in our OA population and consequently an autologous skin flap transplantation was applied.

The early fascial closure was considered only applicable for light trauma victims[37] and in the case of critically ill patients, a longer time may be required due to serious abdominal infections. The patient population in the present study exhibited a mean APACHE II score of 26. The early abdominal fascial closure that was achieved in 71.4% of the patients in the treatment group and in 12.5% of the patients in the control group, as well as the overall closure rates, were 40% for all patients. The patients that received fluid removal therapy had significantly higher rates of early closure. A recent systematic review demonstrated that early fascial closure has great clinical advantages in reducing the mortality and incidence of complications compared with the delayed abdominal closure.[28] An aggressive approach during the early fascial closure was suggested to be considered as an initial form of treatment in OA management. The clinical advantages of early closure, however, were not further confirmed by the results of the present study. The length of ICU stay and initial hospital stay were not significantly different between the 2 groups ($P > .05$), which may have occurred due to the small sample size. In addition, the patients who failed to have an early fascial closure were discharged initially following stabilization and then readmitted for the definite surgery of abdominal wall reconstruction. In this case the total hospital stay would be lengthened.

Fluid management is an essential component in maintaining hemodynamic stability, tissue perfusion, and organ function for critically ill patients.[38] Aggressive volume resuscitation of crystalloid has been reported to correct hemodynamic and metabolic derangements. However, it may result in volume overload and increased risks of ACS and pulmonary edema, thus inhibiting early fascial closure. In addition, Goussous et al[39] demonstrated that fascial closure was associated with lower fluid balance in OA patients. In the present study the patients who received fluid removal therapy of torasemide and/or CRRT had significantly higher rates of early fascial closure rates. The abdomens of the patients successfully closed at $6 \pm 0.5$ days following initiation of OA. Furthermore, the patients with fluid removal therapy exhibited significantly greater weight loss and significantly lower IAP since day 5 compared with the control group.

The limitations of the study could be attributed to the single center, the small sample size, and the non-randomized design that may be a source of potential biases. The patient allocation in this study was based on the consent and the choice of patients and their families. The latter parameters will require additional analysis in future studies.

It has been reported that at present the definitions of indications, applications, and methods to close the OA are still a matter of debate, since no definitive data has demonstrated the actual differences between the different techniques that have been used to maintain the OA in terms of morbidity and mortality. According to previous studies the impact of the different kind of nutrition on the outcomes has not been defined,[40–43] whereas the majority of studies have selected patients in at least a few centers with many different biases.[44–48] Lastly, the lack of sufficient data to support the closure and follow-up of the patients treated with OA strategies is a significant disadvantage of the study design that requires to be addressed in future studies.[49–51]

## 5. Conclusion

In conclusion, fluid removal therapy possibly can enhance the rates of early fascial closure in open abdomens with VAWCM treatment and facilitate the early primary facial closure within 1 week of treatment. An aggressive approach at the early fascial closure may be considered an initial option in OA management.

## Author contributions

**Conceptualization:** Qian Huang, Yunzhao Zhao.
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