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Novel Application of Vacuum Sealing Drainage with Continuous Irrigation of Potassium Permanganate for Managing Infective Wounds of Gas Gangrene*

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Summary: Traumatic gas gangrene is a fatal infection mainly caused by *Clostridium perfringens*. It is a challenge to manage gas gangrene in open wounds and control infection after debridement or amputation. The aim of the present study was to use vacuum sealing drainage (VSD) with continuous irrigation of potassium permanganate to manage infective wounds of gas gangrene and observe its clinical efficacy. A total of 48 patients with open traumatic gas gangrene infection were included in this study. Amputations were done for 27 patients, and limb salvage procedures were performed for the others. After amputation or aggressive debridement, the VSD system, including polyvinyl alcohol (PVA) foam dressing and polyurethane (PU) film, with continuous irrigation of 1:5000 potassium permanganate solutions, was applied to the wounds. During the follow-up, all the patients healed without recurrence within 8–18 months. There were four complications. Cardiac arrest during amputation surgery occurred in one patient who suffered from severe septic shock. Emergent resuscitation was performed and the patient returned to stable condition. One patient suffered from mixed infection of *Staphylococcal aureus*, and a second-stage debridement was performed. One patient suffered from severe pain of the limb after the debridement. Exploratory operation was done and the possible reason was trauma of a local peripheral nerve. Three cases of crush syndrome had dialysis treatment for concomitant renal failure. In conclusion, VSD can convert open wound to closed wound, and evacuate necrotic tissues. Furthermore, potassium permanganate solutions help eliminate anaerobic microenvironment and achieve good therapeutic effect on gas gangrene and mixed infection. VSD with continuous irrigation of potassium permanganate is a novel, simple and feasible alternative for severe traumatic open wounds with gas gangrene infection.

Key words: vacuum sealing drainage; potassium permanganate; irrigation; gas gangrene; trauma

Gas gangrene is no doubt one of the most fulminant necrotizing infections that are life-threatening for humans[1]. It is characterized by necrosis and gas formation of soft tissue[2]. Gas gangrene can be classified as traumatic, postoperative, and spontaneous[3, 4]. It is a notorious complication of traumatic wound on war fields[5] and has been recognized in badly contaminated wounds in civilian life[2]. Traumatic and postoperative gas gangrenes are more common types and account for 70% of the cases[6]. There are some species of *Clostridia* (*Clostridium perfringens*, *Clostridium novyi*, *Clostridium septicum*, *Clostridium histolyticum*, *Clostridium bifermentans*, and *Clostridium fallax*) that cause gas gangrene in humans[7]. *Clostridium perfringens* is always associated with open wounds and accounts for 80%–95% of reported cases[8]. Gas gangrene of the limbs is rare, but can be challenging to surgeons due to its high morbidity and mortality[4]. The traditional mainstay of therapies includes supportive care, systemic antibiotic treatment, and often, aggressive surgical intervention[9], in particular, amputations[8].

Vacuum sealing drainage (VSD) has been introduced since 1992[10] and widely used in wound management. It is recommended for virtually all kinds of extensive soft-tissue injuries, contaminated wounds, severe open fractures, skin graft infections, infected surgical incisions, burns, and diabetic chronic ulcers[11, 12]. It can quickly evacuate accumulated secretions or necrotic tissues under the wound surface, and accelerate granulation tissue growth and wound healing[13]. However, there are few reports about use of VSD combined with continuous irrigation of potassium permanganate for patients who suffer from sustained traumatic gas gangrene of the extremities.

Usually, the wounds of gas gangrene are treated

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with open wet dressing, serial debridement of the wound, or amputation[14]. Wound treatment and dressing should be aseptic and strictly standardized to prevent nosocomial infection[15]. In our retrospective study from January 2007 to December 2011, 48 patients suffering from gas gangrene were admitted and treated with VSD combined with continuous irrigation of potassium permanganate and satisfactory outcomes were achieved.

1 PATIENTS AND METHODS

1.1 Patients

A total of 48 patients (32 males, and 16 females) with a mean age of 41 years (range 11 to 67 years) were included from March 2006 to June 2011. Traumas consisted of traffic accidents, crushed injuries, animal bites, and fall injuries. All the cases were open-traumatic injuries. There were 39 cases in the lower extremities and 9 cases in the upper extremities. Seventeen patients had limb fractures, 3 had spinal fractures, and 1 had pelvic fracture. The co-morbidities were traumatic shock (7 patients), hemorrhagic shock (11 patients), septic shock (1 patient), and crush syndrome (5 patients). The mean time interval between injuries and treatment was 42 h, ranging from 6 to 112 h.

Diagnosis of gas gangrene was made based on the typical signs and symptoms (such as fever, pale skin, pain, wound swelling), positive anaerobic culture for *Clostridium* bacteria in wound secretion, and gas formation of soft tissue on the plain radiographs[15]. All the patients in the study suffered from severe pain which exacerbated rapidly. The physical findings included local crepitus and marked swelling. The underlying skin initially appeared pale but turned red, then bronze, and finally, purplish-black color. The lesions rapidly developed blisters which contained a dark and foul-smelling fluid. Plain radiographs revealed gas formation in the muscular layer. CT and MRI were not performed on a routine basis for fear of cross-infection. Smear and Gram stain of pus from the wound revealed leukocytosis and Gram-positive bacilli (*Clostridium* bacteria).

1.2 Treatment

Early diagnosis, aggressive treatment, radical debridement, and amputations (when necessary) are essential to save patients with gas gangrene[4]. Surgical debridement of all involved gangrenous tissues is crucial in preventing progression of infection and subsequent exotoxin production[16]. The wound was supposed to be opened thoroughly, and all necrotic and nonviable tissues to be excised till fresh tissues with abundant blood supply were exposed.

All patients underwent extensive surgical debridement of the affected extremities, and amputation of the infected limb was performed on 27 patients. All patients were administered antibiotic treatment such as penicillin, clindamycin, chloramphenicol, tetracycline, and metronidazole[17]. Supportive care, maintenance of fluid and electrolyte balance, blood transfusion, and constant monitoring were given to the patients. None of the patients was treated with the medical hyperbaric oxygen chamber because its therapeutic value is controversial[18, 19].

1.3 VSD

All VSD devices were supplied by Wuhan VSD Medical Science and Technology Co. Ltd (China). After thorough debridement of all nonviable tissue, the polyvinyl alcohol (PVA) foam dressing was tailored and applied to the wound. The size of pores of foam dressing was 0.3–0.8 mm and allowed in-growth of the maximum tissue. Two non-collapsible silicone drainage tubes were placed into the foam dressing and connected to a computerized vacuum pump. Each tube was placed into the different side of wounds to provide patent and adequate drainage. The wound was then continuously irrigated and was kept clean inside. An additional tube was embedded under the foam dressing through which the wound was continuously irrigated with 1:5000 potassium permanganate solutions. Continuous negative pressure of suction was applied (40–60 kPa) to keep the sponge evenly contacted with the wound bed and to make no dead space[20]. The wound was covered with a transparent polyurethane (PU) film dressing that tightly sealed water out. All of the above-mentioned manipulations were done in an aseptic manner and the volume of flushing fluid was 5000 mL per day. The VSD dressings were changed per 7 days. If the drainage was obstructed, the dressings were changed immediately. During the period, smear examination for wound secretion was done every day to test *Clostridium* bacteria to monitor the progress of the disease.

2 RESULTS

Mean follow-up period was 14 months, ranging from 8 to 18 months. All the patients were healed after these treatments. Twenty-seven patients had delayed in transportation, and thus, their limbs were amputated due to overwhelming infections and serious muscular necrosis of the injured extremities. Of them, 5 cases had second debridement for muscular necrosis. All involved tissues and residual limbs were debrided completely (fig. 1–3). The wounds were closed only if the soft tissues of stumps of the extremities were healthy. The wounds were enclosed by VSD combined with continuous irrigation of 1:5000 potassium permanganate solutions. One patient suffered from severe septic shock when arriving at our hospital. Emergent resuscitation and amputation were conducted. However, cardiac arrest occurred 2 h after the operation. The vital signs of this patient were recovered and became stable after resuscitation. After the debridement, the tissue and fluid cultures were found to be positive for *Clostridium* bacteria. When cultures of the wounds and drainage were performed three times and no bacterial growth revealed, the wounds were sutured and finally healed without recurrence.

Limb salvage procedure was performed on the other 21 patients. Wounds were debrided completely and enclosed by VSD combined with continuous irrigation of 1:5000 potassium permanganate solution. In one patient, the smear of the wound revealed mixed flora of Gram-positive bacilli and Gram-positive cocci. The bacterial culture confirmed mixed infection of *Staphylococcal aureus*. Administration of adequate antibiotics and a sec-

ond debridement were performed on this patient, and the wound finally healed. In another patient, pain of the wound exacerbated 5 days after the first operation. Although culture of the drainage revealed no bacterial growth, an exploratory operation was performed and there were negative findings. VSD, with continuous irrigation of potassium permanganate solution, was retained after the second debridement, and the wound healed finally. Severe pain of this patient may be due to trauma of a local peripheral nerve. For the other patients, even the tissue and fluid cultures were first positive for *Clostridium* bacteria. Cultures of the wound revealed no bacterial growth after continuous irrigation. No recurrence happened and wounds were closed by suture or skin graft.

The serum potassium was elevated 3 days after irrigation in 5 cases of crush syndrome. And 3 of the patients were given dialysis treatment for concomitant renal failure. Not any change of the serum potassium or sodium was found in the others in the absence of crush syndrome during irrigation. The irrigation of potassium permanganate solutions had no any effect on the elevation of serum potassium or dilution of serum sodium. The results of blood electrolyte, blood gas analysis, serum biochemical levels and oxygen saturation were normal, and there was not any systemic absorption of the potassium permanganate.

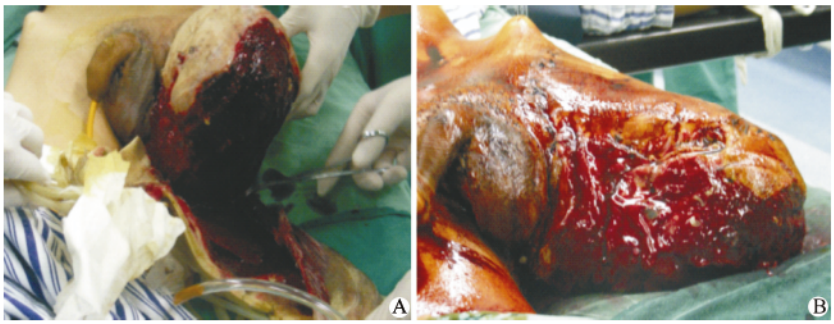

Fig. 1 View of the wound before the second debridement (A) and extensive surgical debridement and disinfection of the wound (B)
The trauma in the left lower leg was caused by machine-induced damage and the first operation was amputation. Smear of pus of the wound revealed Gram-positive bacilli 48 h after the emergency amputation.

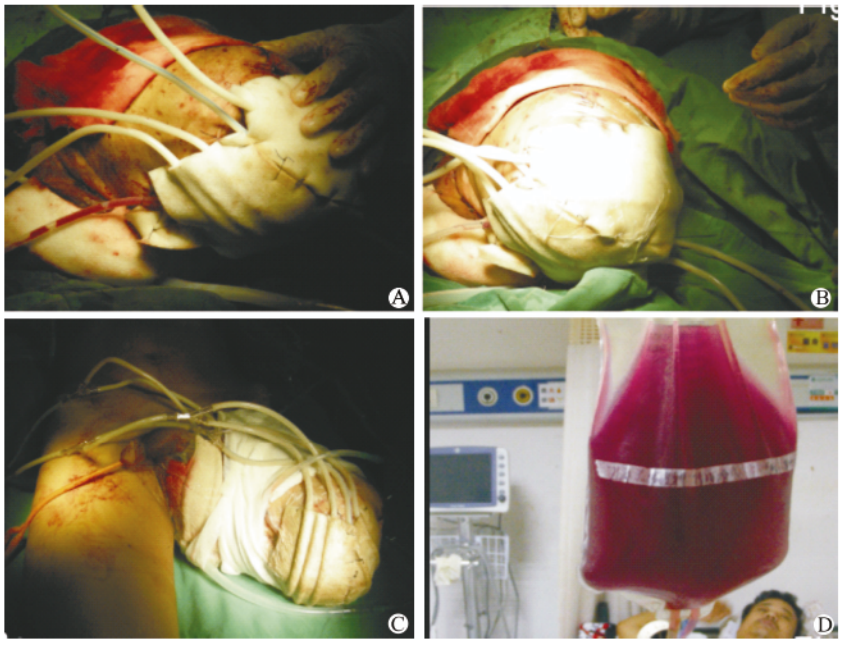

Fig. 2 The second operation of VSD dressing combined with continuous irrigation of potassium permanganate
A: The shaped PVA foam dressings were applied and fixed to the wounds. The drainage tubes were placed into the foam dressing. B: The transparent PU covered the wounds and the foam dressings. C: The wound endangered the perineum. One drainage tube was placed into the rectum in order to discharge the intestinal secretion. D: The wounds were irrigated with 1:5000 potassium permanganate solution.

3 DISCUSSION

Gas gangrene, caused mainly by the anaerobic bacteria *Clostridium perfringens*, is an emergent infectious disease and a serious threat to limbs and lives[21, 22]. *Clostridia perfringens* are Gram-positive, spore-forming, nonmotile, anaerobic bacilli and are widely distributed in virtually all soil types and in the guts of almost all animal

species[23]. Trauma introduces organisms into the deep tissues and produces an anaerobic microenvironment with a sufficiently low redox potential and acid pH for optimal *Clostridia* growth[1]. Only 1000 to 3000 cases of gas gangrene per year are reported in the United States; but fatal infection often results from rapid invasion and destruction of muscle tissue[9]. Because gas gangrene progresses very rapidly, aggressive surgical exploration and debridement is critical and should be performed as soon as possible[2]. Some authors suggested that the intervention should be combined with antibiotic and hyperbaric oxygen therapy[24]. Although certain achievements have been made, management of the open wounds and control of cross-infection are still problems that need urgent solution.

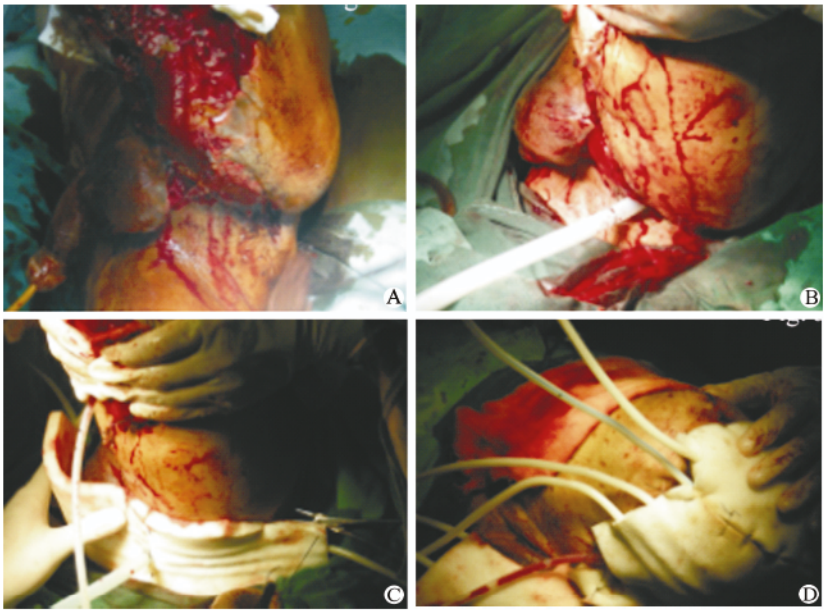

Fig. 3 The progress of the third operation

A: The view of the wounds after the first usage of VSD and irrigation with potassium permanganate solution for 10 days. Smear of drained fluid did not reveal Gram-positive bacilli. B: One drainage tube was still placed into the rectum in order to discharge the intestinal secretion. C: The shaped PVA foam dressings were fixed to the other unclosed part of the wounds and the perianal wound. D: The irrigation with 1:5000 potassium permanganate solution was used after the third operation.

In general, wounds in gas gangrene cases are usually left open after wound debridement or amputation followed by periodical cleaning and dressings. The pathogen *Clostridia* can infect other patients not only through direct contact transmission but also through airborne transmission. The keys to prevent nosocomial cross-infection are the standard procedures suggested by Chen *et al*: (1) all patients should enter wards, surgical rooms, or specifically designated treatment rooms such as hyperbaric oxygen chamber through peculiar routes; (2) the used wound dressing should be disposed of safely for decontamination; (3) renew clothes and beddings at regular intervals, i.e. every day. The used items should be treated independently; (4) disinfection of wall space and floor should start immediately after the intervention procedure by standard practice[15].

The procedures were strictly performed according to the above standard protocol in our study; however, cross-infection usually could not be completely avoided during transportation and treatment. If incautious, catastrophic consequences will follow. Long-term wet dressing of the wound may cause physical discomfort, psychiatric stress of the patient, mixed infection of the wound, osteomyelitis, and delay union or nonunion of fractures[14]. Wound management of the extremities in traumatic gas gangrene probably represents the most demanding field. The optimal methods of treatment should be sought.

The VSD system has been initiated since 1992; since then, numerous clinical and basic studies have shown its advantages for both open and closed wound treatment[25, 26]. It was originally designed as an aid to chronic wound healing[11]. However, based on subatmospheric pressure, it has revolutionized to manage various kinds of acute and chronic wounds[12]. In the present study, 48 patients with traumatic gas gangrene infection were treated with VSD combined with continuous irrigation of potassium permanganate. With this system, the region of soft tissue loss became a closed wound with a controlled environment.

Vacuum sealing offers an optimized drainage system independent of gravity[26]. The drainage is complete and can cover the wound surface, and is unrestricted by postures[13]. By means of full contact with the wound, the entire part of the wound surface can be drained adequately. *Clostridia* contaminants, the flushing liquor, accumulated secretions, and necrotic tissues are all evacuated away into a closed drainage system. Furthermore, there is less chance that bacterial toxins and inflammatory tissues enter the blood stream, which is significantly

helpful to improve the general condition of patients.

Positive tissue and fluid cultures after debridement as proof showed that we did not over-debride. The adjunctive permanganate irrigation is necessary. The improvement of hypoxic condition at the wound site is also important. The wound can be cleaned with 3% hydrogen peroxide or 1:5000 potassium permanganate solution[15]. Hydrogen peroxide could cause air emboli in the suction tubes. The 1:5000 potassium permanganate solution, as a strong oxidant, not only eliminates an anaerobic microenvironment for optimal *Clostridia* growth, but also directly kills the pathogenic bacteria by oxidation. Even in a mixed-infection condition, the wash with potassium permanganate solution also provided adequate therapeutic effect. In addition, the irrigation of potassium permanganate solutions did not have any effects on the elevation of serum potassium or dilution of serum sodium. And there was not any systemic absorption of the potassium permanganate.

Additionally, in the current study, the transparent PU drape served as an enclosed barrier to avoid the leakage of flushing fluid containing *Clostridia*, but allowed diffusion of gas. The wound could easily be inspected through the transparent drape. Frequent dressing change causes tremendous suffering for patients and can be time consuming for the medical staff. With this system, it is unnecessary to change dressings frequently. Fewer dressing changes usually mean less pain and greater comfort. VSD has been shown in other studies to be less painful and even more logistically efficient when staffing time is incorporated[25]. It can eliminate edema and dead space[27]; can stimulate the growth of healthy granulation tissue[13]; can improve local blood flow and perfusion; and can provide oxygen, nutrients and inflammatory cells[28], thus facilitating wound healing[20, 29]. VSD for promoting granulation growth and accelerating wound healing has been proven at the molecular and cellular levels[14, 23]. Besides, VSD has the the advantage of simplifying secondary surgery[30].

To sum up, VSD technology has a wide range of applications in wound management. The indications for VSD therapy are still quickly expanding. In this study, the authors successfully treated 48 cases of traumatic gas gangrene infection by using VSD combined with continuous irrigation of potassium permanganate (1:5000). The present study could demonstrate that VSD with continuous irrigation of potassium permanganate is a novel, simple, and viable alternative for treating problematic wounds of traumatic gas gangrene infection in extremities.

Conflict of Interest Statement

The authors declare no conflict of interest in this work.

Ethical Considerations

This work was performed to the principles expressed in the Declaration of Helsinsky. This study was approved by the Ethical Committee in Union Hospital of Tongji Medical College, Huazhong University of Science and Technology, China, and informed consent was obtained from all patients preoperatively. The registration number of this trial was ChiCTR-ONC-12002264. The level of evidence was level IV.

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