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Research Article

The Use of Negative Pressure Wound Treatment of Chronic Non-Healing Wounds

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Abstract

Treatment of chronic non-healing wounds in the lower extremities involves a variety of comprehensive treatments, including dehydration by vacuum-assisted closure (VAC) therapy, plastic closing surgical techniques, etc. The aim of the study was to analyze the results treatment of chronic non-healing wounds of lower limb with have used with VAC therapy. The retro- and prospective study included a review of data collected from 127 patients in 2011 - 2020 of both sexes with mean age of 59.8 years. All patients were divided into three groups: the 1st group (49), who after opening and sanitizing the purulent cavity was prepared the wound for the application of secondary sutures or for autodermoplasty by an open method using bandages with proteolytic enzymes, ointments on water-soluble basis, antiseptics; the 2nd group (57), who underwent VAC therapy after necrectomy, and the 3rd group (21), who underwent preparation of long-existing infected granulating wounds for autodermoplasty. The patients had initial local and systemic treatment, followed by VAC therapy, and were statistically analyzed. In 62 patients additional treatment was not required, in 25 patients were needed including a surgical plastic closing of your own skin. The 2 patients died before final closure due to other complications (myocardial infarction and stroke). In all the other patients, their wounds are completely healed. In order to eradicate the infection and close the wound the duration of VAC averaged 6.3 ± 0.32 days (from 2 to 16 days). The study confirmed the safety and effectiveness of VAC bandages in patients as to primary treatment and preparing this patients for autodermoplasty.

Keywords: Chronic Non-Healing Wounds; Lower Limb; Surgery; VAC Therapy; Surgical Treatment; Results

Introduction

Healing the wounds throughout the history of civilization has not lost its medical and social significance. The economic and technological progress was not guarantee that the individual will be spared both natural and techno-genetic factors capable of causing severe damage nowadays. In addition, a number of chronic diseases, compounded by chronic wounds such as diabetes mellitus, chronic vascular and neurological pathology, trauma have a significant upward trend in injuries. Lesions of the lower extremities occur in 30 - 80%, often facilitated by violations of carbohydrate and other types of exchange [1]. According to epidemiological studies, amputations are performed by patients with diabetes mellitus 10 - 15 times more frequently than in the total population, accounted for 50 - 70% of all performed surgery interventions [2].

Skin wounds are a heterogeneous group of diseases with a wide varities of causes. Most wounds heal through well-known pathophysiological stages, and those that do not heal for a long time are considered chronic. Despite the lack of consensus on the definition, most wounds are called acute if they are present only for a short

period of time before the intervention (< 4 weeks to a maximum of 6 weeks) and show signs of normal wound healing [3]. Chronic wounds are defined as those that are present from one month to 6 weeks prior to the intervention without any tendency towards normal wound healing. These wounds either take a long time to heal, or do not heal completely, or they often recur [4]. Studies of chronic wounds have highlighted that numerous factors, such as a deficiency of local systemic growth factors, changes in the extracellular matrix, decreased function of fibroblasts, decreased antimicrobial activity of leukocytes, presented of biofilms and impaired macro- and microcirculation, are responsible for slowing the healing of these wounds [5]. Physical factors for healing wounds have the longest history of use. All the more interesting is the fact that, at the beginning of the twenty-first century, a breakthrough in the treatment of wounds was linked to what has long been a known phenomenon with used of treatment of low pressure. Even more impressive are the successes of the use of VAC therapy recent years. It is known that a wound is a defect of internal organs, skin coverings, mucous membranes and the tissues, developed to results of a mechanical, physical, chemical, or biological action, as well as by a disorder of blood supply or innervation. The wound is a dynamically developing formation that undergoes certain structural changes from its formation to its healing. In the first stages, the wound cavity is filled with the wound contents (in transudate or exudate, necrosis), then with granulation tissue, and finally with an epithelium in the result of healing. All wounds, although they have common measures of the character of their development and healing, are nonlinear in origin, size, localization, depth, peculiarities of the clinical course of the wound-process, etc. It particular difficult in clinical practice are wounds that do not heal for a long time and often constitute lesions not only of the skin but also of its appendages. The bottoms of such wounds often are fat fiber and deeper underlying tissues (fascia, muscles, bones, internal organs, etc).

Wound healing is a natural process that consists of a series of morphofunctional changes in tissues occurring at the molecular, cellular and tissue levels and effecting the whole body to varying power. Regardless of the cause and type of the wound, its healing follows a standard pattern and has the same structural-functional changes that begin with blood clotting, formation of eschar, wound cleansing from micro-organisms, foreign bodies, primaries or secondary dead tissues and ending with the formation of a new granulation tissue subsequently covered by the epithelium. VAC is one of the treatment methods used to improved results of treatment. It was used for primary treatment of chronic and complex wounds, as well as for supplementing conservative therapy or preparing the wound for surgery. The method is widely and successfully used in most clinics, although the full physiological basis of the method is not clear nowadays.

The modern VAC was developed by staffs at Wake Forest Medical University (USA) in the 1990s [6], which had been used an additional treatment of wounds to remove the exudate from the wound through an airtight bandage and a special tube connected to the container. The pathogenesis of the formation of chronic wounds has not been studied enough, although much is already known in this direction. One of its main links is a violation of the blood supply to tissues as a result of the following main reasons: a decrease in blood flow and oxygen supply, blood shunting, disorders of venous and lymphatic outflow, metabolic disorders, infectious and autoimmune processes, etc. Physicochemical conditions in which healing takes place are of great importance in the normal tissue repair. The studies of G. Winter (1962) had been showed the special effect of a moist environment on self-cleaning of the wound, proliferation and migration of epithelial cells. It was found that with a sufficient amount of water in the extracellular matrix, a looser fibrous tissue is formed with the subsequent formation of a less coarse but more durable scar. Currently, a large number of wound dressings have been created that retain a certain power of influence in the wound [7].

It is known that the wounds healing process can be divided into main stages: 1) hemostasis (control of bleeding); 2) inflammation (removal of debris, control of infection, clearance of inflammation); 3) proliferation (angiogenesis, formation of granulation tissue, contraction); and 4) remodeling (remodeling of the connective tissue matrix, and maturation). Because growth factors, cytokines, proteases, and cellular and extracellular elements plays of important roles in different stages of the healing process, imbalances of one or more of these components may account for the impaired healing observed in chronic wounds [8]. The levels of various MMPs (collagenase, gelatinase A and B) and be also serine proteases are markedly increased in fluids from chronic wounds, whereas MMP levels are lower in acute wound healing. Other proteases, such as neutrophil elastase, have also been observed to be significantly higher in chronic wounds. Elevated levels of serine proteases de-

grade fibronectin, an essential protein involved in the remodeling of the extracellular matrix (ECM) [9].

Analysis of various publications showed that VAC effects data can be divided into the following groups: 1. Extracellular, when there are an increase in extracellular blood flow and a decrease in edema, which has a positive effect on the wound environment [10-12]. 2. Cellular, when the formation of ranulation tissue and cell synthesis occurs [13-17]. 3. Complex, when the body is able to carry out wound processes such as healing, infection control and exudate control [18-21].

Given the positive impact of VAC-therapy on the course of the infected processes, this method has become widely have been used in the treatment of wounds with complications in various areas of surgery [22-28]. Several authors have noted the clinical and economic efficiency of VAC for various types of wounds [29]. Indeed, VAC recommended when surgical treatment, reconstructive surgery, or autodermoplasty under local or general anaesthesia is contraindicated [30]. However, other authors point out the negative aspects of VAC in some patients, such as the sense of dependence on the device, reduced mobility, sleep disturbances, and pain upon removal of film or sponge. Thus, an individualized approach to patient management, as well as additional training for both patient and staff is suggested [31-35]. Nevertheless, the results of several meta-analyses demonstrate a higher efficiency of local negative pressure therapy compared with that of other methods in the treatment of various wounds, particularly with respect to preventing wound infections, improving perfusion of wound tissues, and shortening the wound-healing period [36,37]. The method can be tailored for an outpatient setting with the use of portable suction devices [38].

Aim of the Study

The aim of the study was to analyze the results treatment of chronic non-healing wounds of lower limb with have used a VAC therapy.

Materials and Methods

The retro- and prospective study included a review of data collected from 127 patients in 2011 - 2020 of both sexes with an average age of 59.8 years, who were treated in the Department of Surgery in Kharkiv Regional Hospital and in Merefyanska Central District Hospital, Ukraine. All patients were divided into three groups: the 1st group (49), who after opening and sanitizing the purulent cavity was prepared the wound for the application of secondary sutures or for autodermoplasty by an open method using bandages with proteolytic enzymes, ointments on water-soluble basis, antiseptics; the 2nd group (57), who underwent VAC therapy after necrectomy, and the 3rd group (21), who underwent preparation of long-existing infected granulating wounds for autodermoplasty. Criterias of inclusion to VAC therapy were: existence of chronic non-healing wounds that requires surgical intervention; the wound area is > 50 cm^2; presence of signs of systemic inflammatory reaction and disorders other systems due to intoxication. Criterias of exclusion to VAC therapy were: eczema around the entire wound; malignant degeneration of the wound; blood clotting disorders; dementia and other mental disorders. On admission, all patients underwent clinical and biochemical blood tests, assessed the functional state of the cardiovascular, respiratory, urinary systems, as well as liver functions.

After surgical treatment of the purulent focus, local treatment of the wounds in patients of the 1st group was carried out using local antiseptics and ointments on a water-soluble basis; in patients of the 2nd and 3rd groups the VAC therapy was used in continuous mode with a vacuum of 125 mm Hg with dressing change after 48 - 72 hours. A porous polyurethane material was applied to the prepared wound surface, cut out exactly along the contour of the wound so that the dimensions and contours of the wound cover corresponded to the contours of the wound defect at all bends of the limbs (Figure 1 and 2).

The bandage was prepared, transferred and straightened on a flat surface which was preliminarily photographed using a digital camera along with a predetermined area standard for which a centimeter ruler was used as a marker. To calculate the area of the wound, the resulting image of the wound covering was processed using the lpSquare computer application. The prepared vacuum bandage was applied to the wound and vacuum therapy was performed [39].

Figure 1: Infected wound of the right groin and right thigh: a) installation of the VAC; b) the wound on the 8th day of treatment was prepared for the formation of secondary sutures.

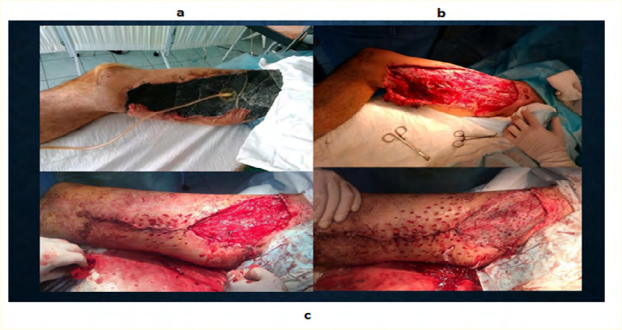

Figure 2: Extensive purulent-necrotic wound of the right thigh: a) installation of the VAC; b) the type of wound on the 14th day of the treatment; c) plastic closure of the wound.

Bacteriological studies of biopsy specimens included qualitative (species) and quantitative analyses of the microflora in the soft tissue. The identification of isolated microorganisms was carried out on the basis of their morphological characteristics. The level of bacterial contamination was determined in 1g of wound tissue. The bacterial contamination of the wound tissues from both groups averaged 6.84 ± 0.67 CFU/ml on a logarithmic scale.

All patients were analyzed using statistical methods and the 'Biostatistics' program package (Russia). In the study of quantitative traits for comparison of 3 groups used the Student's t-test, and for a small number of groups, nonparametric Mann-Whitney test. For comparison of indicators within one group at different points in time - paired Student's t-test, and comparisons between groups. The results were considered significant at 95% or more.

Results

After admission to the hospital, according to clinical analyzes of pronounced inflammatory changes, the WBC was averaged 13.5 ± 2.2 × 10^9/L (from 9.6 to 14.8). The results of microbiological studies of wounds discharge taken during the surgical treatment of purulent foci was an important criterion, including for the use of rational antibiotic therapy. Various microorganisms were isolated from the wound discharge both in monoculture and in associations. The leading place in all patients (n = 127) was occupied by gram-positive microorganisms: *Staphylococcus aureus* and *epidermidis* - in 74 (58.3%) patients; gram-negative microflora was represented by *E. coli* - in 27 (21.3%) patients, *Enterobacter* - in 9 (7.1%), *P. aeruginosa* - in 4 (3.3%). In 13 (10.2%) patients of the 3rd group cultures from wounds did not reveal microorganisms. The level of bacterial contamination was 6.84 ± 0.67 CFU/ml, 6.53 ± 0.48 CFU/ml, 5.78 ± 0.87 CFU/ml in all groups (p_1 = 0.007, p_2 = 0.000, p_3 = 0.000, respectively). The area of trophic ulcers at the initial stage of treatment averaged 34.22 ± 4.17 cm^2, 54.43 ± 4.12 cm^2 and 58.34 ± 3.1 cm^2 (p_1 = 0.000, p_2 = 0.000, p_3 = 0.000, respectively). On the 14th day of the treatment in patients of the 1st group WBC were 11.23 ± 1.2 x 10^9/L, in the 2nd were 9.14 ± 1.1 × 10^9/L, in the 3rd were 7.21 ± 0.98 x 10^9/L, respectively (p_1 = 0.000, p_2 = 0.000, p_3 = 0.000). The level of bacterial contamination were 4.72 ± 0.62 CFU/ml, 3.65 ± 0.73 CFU/ml and 2.89 ± 0.43 CFU/ml, respectively (p_1 = 0.000, p_2 = 0.000, p_3 = 0.000).

At the same time in the 1st group *S. aureus* and *Staphylococcus epidermidis* were most often detected - in 31 (63.3%) patients, as well as Providencia - in 5 (10.2%), *P. aeruginosa* - in 5 (10.2%), *Enterobacter* - in 3 (6.1%), *Proteus* - in 3 (6.1%), *E. coli* - in 2 (4.1%). The area of the wounds averaged 32.7 ± 11.14 cm^2. In the 2nd group *S. aureus* and *Staphylococcus epidermidis* were most often detected in 39 (68.4%) patients, in addition Provincia - in 7 (12.3%), *Enterobacter* - in 5 (8.8%), *E. coli* - in 4 (7.02%), *P. aeruginosa* - in 2 (3.5%). The area of the wounds averaged 46.54 ± 10.56 cm^2 during that period of treatment of the patients. In the 3rd group of patients the wound area was 55.67 ± 10.56 cm^2 by the 14th day of the treatment. Of the 57 patients in the 2nd group, VAC was used

once in 39 (68.4%) patients, twice in 14 (24.6%) patients, and thrice in 4 (7.02%) patients. On average, 1.4 ± 0.11 bandages of local negative pressure were used a patient. Of the 21 patients in the 3rd group, VAC was used once in 19 (90.5%) patients and twice in 2 (9.5%) patients. On average, 1.2 ± 0.1 VAC dressings were applied to patients in the 2nd group and 1.13 ± 0.08 VAC dressings in the 3rd group (p = 0.002). The duration of VAC ranged from 2 to 16 days and averaged 6.3 ± 0.32 days. The average number of dressings per patient was 13.4 ± 1.12 in the 1st group, 1.84 ± 0.34 in the 2nd and 3rd groups (p = 0.000).

Discussion

Treatment of various wounds and the use of negative pressure (NTWP) is widely used in clinical practice in patients with acute and chronic wounds, when a vacuum source creates continuous or periodic negative pressure inside the wound, which promotes the removal of fluid and infectious substrates, healing and closure of wounds [40-42].

By the end of the 19th century, Professor August Bier defined the concept of cupping by a method of igniting alcohol within a glass and placing a rubber tube on the skin prior to application of the heated cupping glass. In 1908, Bier's hyperemic treatment method was described and since then vacuum therapy has been used for the treatment of all types of open wounds (traumatic, chronic, and postoperative) as well as for the treatment of infections [43]. In the treatment of grave wounds, two interrelated tasks are solved: these are the suppression of the microbial causative agent of infection and the creation of favorable conditions for the healing of the wound defect. The components of the treatment program are: surgical debridement of the focus of infections, antibacterial therapy, detoxification and transfusion therapy, nutritional support [43]. One of the new methods used in the treatment of wounds is the located prolonged use of negative pressure. VAC therapy reduces the intensity of the wound by helping to maintain the wet environment in the wound to create optimal healing conditions. The methodology is based on the use of special sponges and vacuum generator, which creates negative pressure in the wound, resulting in the removal of pathological exudate, reducing the bacterial burden of the wound and stimulating the growth of the granulation tissue and epithelia. One of the cause for the change in treatment tactics in favor of the use of skin grafts is the development of a large number of complications during healing of wounds, as well as the impossibility of full using of the legs by these patients when they walking.

With the long-term existence of the defect, the probability of reinfection increases many times. The timing of surgical closure of skin defects in patients depends on the severity of purulent-necrotic lesions, the area of the lesion and compensation for concomitant pathology. During VAC therapy, there is an active removal of excess wound exudate, including the removal of substances that slow down the wound healing process. The elimination of bacterial contamination and the reduction of the wound are accelerated, as research has shown. When talking about the economic benefits of VAC therapy it should be noted of vacuum dressings. Using this method of treatment reduces the chance of wound reinfection, which eliminates the need for frequent dressings over a long period of time, and readmission to the hospital, which reduces the risk of infection of the wound with hospital strains of microorganisms [44-46]. In addition, the duration of the systemic antibiotic therapy is reduced and funds for treatment are significantly saved.

Conclusion

To sum up, we would like to point out that in many studies it was concluded that when using VAC therapy it promotes an increase in the rate of formation of granulation tissue and when using autodermoplasty methods to close large wounds, overall graft survival and patients compliance are significantly better in the group of patients who were treated with vacuum closure bandage versus the traditional bandage group. It have been using of VAC for patients with chronic non-healing wounds helps to speed up wound clearance and decontamination, eliminates inflammation, hospital stay and reduces wound size, and minimizes the risk of increased cost of treatment and secondary infection nowadays. In addition, the use of this method makes it possible to shorten the preparation time for various methods of autodermoplasty with a significant skin deficiency. It was also noted by most investigators that the total time of hospital stay and the percentage of postoperative complications were significantly less in the vacuum dressing group. Thus, a vacuum-assisted dressing can be considered the best treatment for chronic wounds. But in the future, further research with more patients will be required before a vacuum dressing can be added to the wide range of treatments available in chronic wound management.

Ethical Approval

The work cleared by the Ethics Committee of Kharkiv National Medical University, Ukraine (the protocol №8, October 12, 2020).

Conflict of Interest

The authors declare no conflict of interest.

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