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The clinical outcome of wound healing of open fractures with the use of vacuum assisted closure dressing

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Abstract
A wound is defined as an injury creating a disruption in the normal anatomical structure and function of the skin. There are two different types of wounds: vulnus that is an acute wound, which heals according to the normal wound healing process, and ulcus that is defined as hard-to-heal wounds (previously labeled chronic wounds) such as leg ulcers, pressure ulcers and diabetic foot ulcer. This was a prospective study. Source of study were the 40 Cases satisfying the inclusion criteria. Wounds were initially debrided and vacuum assisted dressing applied. Wounds were assessed depending on wound size and score before and after the application of VAC and the number of VAC settings required for uniform healthy granulation tissue formation was noted. VAC Increases the local blood flow to the wound. It considerably decreases the bacterial load of the wound and thus wound infection. VAC maintains an acidic pH and low oxygen tension on the wound which promotes granulation tissue formation and angiogenesis. Negative pressure wound therapy Induces mechanical stretch on the cell cytoskeleton leading to the release of cytokines associated with wound healing. VAC also reduce wound size, accelerates granulation tissue formation and lower the coverage complexity down the 'reconstructive ladder' when applied as a temporary dressing to acute open fractures.

Keywords: Compound fractures, Vaccum assisted closure, VAC

Introduction
A wound is defined as an injury creating a disruption in the normal anatomical structure and function of the skin. There are two different types of wounds: vulnus that is an acute wound, which heals according to the normal wound healing process, and ulcus that is defined as hard-to-heal wounds (previously labeled chronic wounds) such as leg ulcers, pressure ulcers and diabetic foot ulcer. These wounds have duration of more than six weeks and often show a disturbed wound healing process due to underlying causes other than direct trauma [1]. The classic model of normal wound healing is divided into three sequential, yet overlapping, phases: inflammatory, proliferative and remodeling. However, this process can easily be interrupted due to several inhibiting factors such as smoking, ischemia in the tissue, diabetes and infections, leading to the formation of a hard-to- heal wound, by definition wounds that have failed to heal within six weeks [1-4]. Wounds may heal by three principles: primary, secondary or tertiary healing. Primary healing occurs when the wound edges are put together, often with sutures, and healing occurs with minimal tissue defects. Secondary healing occurs in open wounds, when the wound edges are not put together and healing occurs with formation of granulation tissue. Tertiary healing is delayed primary healing and occurs when a wound is allowed to heal openly for a few days and then is closed with secondary sutures as if primarily.
The concept of recorded wound care goes back to circa 2200 BC, when "three healing gestures" were chiselled into the famous Sumerian clay tablet: washing the wound with beer and hot water, making plasters (mixtures of herbs, ointments, and oils), and bandaging the wound [6]. Ancient Egyptian treatment for open wounds using a paste of grease, honey and lint, is documented in papyruses dating back to 1400 BC. Hippocrates (circa 400 BC) detailed the importance of draining pus from the wound, and Galen described the principle of first and

second intention healing [7-30]. The earliest accounts of wound healing date back to about 2000 B.C., when the Sumerians employed two modes of treatment: a spiritual method consisting of incantations and a physical method of applying poultice like materials to the wound. The Egyptians were the first to differentiate between infected and diseased wounds compared to non-infected wounds. The 1650 B.C. Edwin Smith Surgical Papyrus, a copy of a much older document, describes at least 48 different types of wounds. Ebers Papyrus, 1550 B.C., relates the use of concoctions containing honey (antibacterial properties), lint (absorbent properties), and grease (barrier) for treating wounds [8]. The Greeks, classified wounds as acute or chronic in nature. Galen of Pergamum (120-201 A.D.,), appointed as the doctors to the Roman gladiators, emphasized the importance of maintaining a moist environment to adequate healing. It was shown later that epithelialization rate increases by 50% in a moist wound environment when compared to a dry wound environment [8].

Antisepsis was championed by Ignaz Semmelweiss (1818-1865) who noticed that the incidence of puerperal fever was much lower if medical students, after cadaver dissection class and before attending childbirth, washed their hands with soap and hypochlorite. Louis Pasteur (1822-1895) was instrumental in dispelling the theory of spontaneous generation of germs and proving that germs were always introduced into the wound from the environment [8]. Joseph Lister (1827-1912) probably made one of the most significant contribution to wound healing. He is credited as developing the first antiseptic dressing in 1867 by soaking lint and gauze in carbolic acid [7]. Lister noted that water from pipes that were dumping waste containing carbolic acid (phenol) was clear. In 1865, Lister began soaking his instruments in phenol and spraying the operative rooms, reducing the mortality rates from 50 to 15%. After attending an impressive lecture by Lister in 1876, Robert Wood Johnson (American industrialist and co-founder of company Johnson Johnson) began 10 years of research that ultimately resulted in the mass production of an antiseptic dressing in the form of cotton gauze impregnated with iodoform [8]. Polymeric dressings were developed in the 1960s and 1970s [3]. The discovery of cytokines and growth factors in the 1950s opened a new age in wound healing research. The original description of negative pressure-assisted wound therapy (NPWT) was presented by Argenta and associates in 1997 [3]. Phases of Wound Healing Wound healing has traditionally been divided into three distinct phases [10].

- **Phase of Preparation or Phase of Inflammation:** Hemostasis and Inflammation (Immediately upon injury through Day 4 to Day 6) Wounding by definition disrupts tissue integrity, leading to division of blood vessels and direct exposure of extracellular matrix to platelets [8].
- **Phase of Proliferation:** Angiogenesis Provisional and Matrix Formation. Epithelization (Day 4 through Day 14) Fibroblasts and Endothelial cells are the predominant cells proliferating during this phase. Fibroblasts migrate into the wound site from the surrounding tissue become activated and begin to proliferate. The fibroblast is the surgeon's cell arriving in the scene to synthesize the collagen and ground substance of wound repair.
- Phase of Maturation or Phase of Re modelling.

Methods

This is a prospective study. Source of study were the 40 Cases satisfying the inclusion criteria admitted in tertiary care center during the study period of November 2016 to October 2018.

Inclusion Criteria

1) Patients with Gustilo Anderson type 3B Open fractures, where primary closure is not possible.

Exclusion Criteria

1) Pathological fractures with untreated osteomyelitis.
2) Presence of a thick, necrotic eschar in wound.
3) Patients with hemophilia or haemoglobinopathies.
4) Open fractures that could be primarily closed in initial surgery without requiring flap or split skin grafting.

Method of Applying VAC Dressing

Sequence of Procedure

Wound Preparation Any dressings from the wound are removed and discarded. A culture swab for microbiology should be taken before wound irrigation with normal saline. Surface slough or necrotic tissue are surgically debrided and adequate hemostasis achieved. Prior to application of the drape, the peri-wound skin is prepared and ensured that it is dry. Sharp edges or bone fragments eliminated from wound area or covered. Placement of Foam Sterile, open-cell foam dressing is gently placed into the wound cavity. Fenestrated evacuation tube is embedded in the foam which is connected to a computer-controlled vacuum pump that contains a fluid collection canister.

Sealing with Drapes

The site is then sealed with an adhesive drape. (Opsite). Drapes cover the foam and tubing and at least three to five centimeters of surrounding healthy tissue to ensure a seal.

Orthopedic Hardware

The V.A.C. Dressing can be placed on wounds with orthopedic hardware, such as pin sites. • Appropriate V.A.C. Dressing is placed on the wound. • Moldable hydrocolloid strip around pin approximately is applied 1/2 inch above the level of wound, wrapping it around the pin, ensuring snug fit. • V.A.C. Drape is cut to appropriate size and applied to wound. Strips VAC of drape are cut and applied vertically over the pin and onto main V.A.C. Drape surrounding the pin. This is done from both sides of the pin. Drapes are pinched together to form airtight seal.

The Application of Negative Pressure

Controlled pressure is uniformly applied to all tissues on the surface of the wound. The foam dressing is compressed in response to the negative pressure. The pump can deliver either continuous or intermittent pressures, ranging from 50 to 200 mmHg. Intermittent delivery consists of a sevenminute cycle of two minutes off and five minutes on, while the negative pressure is maintained throughout. Higher pressures of 180-200 mmHg are used for large cavity wounds such as acute traumatic wounds, as they produce copious amounts of exudate. The pressure is set to continuous for the first 48 hours and the pressure is changed into intermittent mode thereafter.

Procedure after the VAC Treatment

Size of the wound is measured, wound score is assessed. Time taken and the number of VAC settings required for the formation of healthy granulation tissue is noted. Second debridement is considered if there is presence of infection and VAC applied after the debridement with the inspection of wound every 24 hours. If the tendons or bone is exposed a secondary procedure of appropriate flap is done. If there is uniform healthy granulation tissue without the exposure of bone or tendon, split skin grafting was done as a secondary procedure.

Results

The present study was undertaken to assess the Clinical outcome of wound healing of open fractures with the use of vacuum assisted closure dressing. More important advances in wound management have occurred recently as a result of expansion of knowledge regarding healing process at the molecular level. NPWT is a novel technique for a managing an open wound by submitting the wound to either intermittent or continuous sub-atmospheric pressure. This a prospective study of 40 patients visiting KIMS hospital with open fractures of Guistilo Anderson grade 3B.Wounds were initially debrided and vacuum assisted dressing applied. Wounds were assessed depending on wound size and score before and after the application of VAC and the number of VAC settings required for uniform healthy granulation tissue formation was noted. In 40 patients, location of open fracture was 72% in leg, 20% in foot and 8% of wounds were with forearm fractures. 30% of patients had initial wound score of 2a, 12.5%had score 2b, and 57.5% had score of 3. Patients with initial wound score 2 showed average reduction of 12.2 mm with appearance of healthy granulation tissue by average of 9 days and patients with initial wound score 3 showed average reduction of 10.3 mm at the end of VAC treatment with appearance of healthy granulation tissue by mean 10.4 days. The mean reduction in size of the wound overall is 11.25mm. 20 patients required flap as a definitive closure procedure where as in 19 patients, wound was closed by split skin grafting. One wound was contracted with VAC treatment. More important advances in wound management have occurred recently as a result of expansion of knowledge regarding healing process at the molecular level. There are several advantages of applying a Primary VAC to an open fracture and these include Vacuum assisted dressing Protects the wound from external environment and further bacterial contamination. It absorbs the exudate from the wound and decreases local edema. It prevents loss of fluid from the wound and thus provides a moist environment at the wound which favors collagen synthesis and epithelial proliferation. VAC Increases the local blood flow to the wound. It considerably decreases the bacterial load of the wound and thus wound infection. VAC maintains an acidic pH and low oxygen tension on the wound which promotes granulation tissue formation and angiogenesis. Negative pressure wound therapy Induces mechanical stretch on the cell cytoskeleton leading to the release of cytokines associated with wound healing. VAC also reduce wound size, accelerates granulation tissue formation and lower the coverage complexity down the ‘reconstructive ladder’ when applied as a temporary dressing to acute open fractures. So we conclude that with VAC, The time duration taken for formation of uniform healthy granulation tissue was less and the rate of wound infection was reduced with early improvement of wound score.

Table 1: Distribution of cases based on age

Sl. No.	Age in years	Number of patients	percentage
1	10-20	3	7.5
2	21-30	14	35
3	31-40	10	25
4	41-50	4	10
5	51-60	8	20
6	>60	1	2.5
Mean age	36.8 years		
Total		40	100

Table 2: Distribution of cases based on sex

Sl. No.	Sex	Number of patients	percentage
1	Male	33	82.5
2	Female	7	17.5

Table 3: Distribution based on mode of injury

Sl. No.	Mode of injury	Number of patients	Percentage
1	RTA	33	82.5
2	Railway accident	5	12.5
3	Accidental fall	1	2.5
4	Fall of heavy object	1	2.5

Table 4: Distribution based on location of injury

Sl. No.	Location of injury	Number of patients	Percentage
1	Leg	29	72.5
2	Foot	8	20
3	Forearm	3	7.5

Table 5: Distribution based on initial size of wound

Sl. No.	Size of wound in mm	Number of patients	Percentage
1	0-50	2	5
2	51-100	23	57.5
3	101-150	13	32.5
4	>150	2	5

Table 6: Distribution based on initial wound score

Sl. No.	Wound score	Number of patients	Percentage
1	Score 0	0	0
2	Score 1	0	0
3	Score 2		
	a. Bone exposed	12	30
	b. Tendon exposed	5	12.5
	c. Implant exposed	0	0
4	Score 3 (bone and tendon exposed)	23	57.5
5	Score 4	0	0

Table 7: Initial wound score and average size reduction in mm after VAC treatment

Sl. No.	Initial Wound score	Average reduction in wound size after VAC
1	2	12.2
2	3	10.3

Table 8: Wound score and time for formation of healthy granulation tissue with VAC

Sl. No.	Wound score	Average time for formation of healthy granulation tissue
1	3	10.4 days
2	2	9 days

Table 3: Duration from time of injury to VAC dressing and number of VAC dressings applied

Sl. No.	Time from injury to first VAC	Average number of VAC dressings applied
1	< 24 hours	4.1
2	<36 hours	4.8
3	<48 hours	4.8
4	<60 hours	6
5	>60 hours	7

Discussion

The use of negative pressure wound therapy in the form of vacuum-assisted closure has been established as a promising method in the field of wound healing in a variety of wounds including those that are difficult to heal. There are two main factors considered to be responsible for the dramatic response seen in these wounds: removal of fluid and mechanical deformation. Removal of fluid decreases edema which decreases the interstitial pressure resulting in increased blood flow. Mechanical deformation causes a wide variety of molecular responses, including changes in ion concentration, permeability of cell membrane, release of second messengers, and stimulation of molecular pathways increasing the mitotic rate of stretched cells. Recently, Scherer *et al.* have concluded that vascular response is related to the polyurethane foam, whereas tissue strain induced by vacuum assisted closure device stimulated cell proliferation.

Duration for Change of Dressing

DeFranzo *et al.* advocated the changing at 2 days interval, while Banwell *et al.* recommend 4-5 days Singh SH *et al.* advocated change at 3-5 days interval. In our study, VAC dressing was changed every 2 days [11, 12].

Rate of Infection Stannard *et al.* studied the impact of NPWT on severely contaminated open fractures and observed significant difference between the 16 groups for total infections. With regular saline dressing, Henley *et al.* reported 34.7% of infection. Charalambous *et al.* reported 27% and, Gopal *et al.* reported 27.4% of infection. Comparatively our study showed overall 12.5% of infection [13, 14].

Our study showed a mean reduction in size of the wound by 11.25 mm after VAC therapy. Study by Kushagra Sinha *et al.* [15]. Showed a decrease in size of 1 to 4.9mm in 26.66% of patients in VAC group whereas 93.33% in control group from day 0 to day 8. A decrease in size of 10 to 19.9mm was seen in 46.66% of patients of VAC group and only 6.66% in control group. A decrease in size of more than 25mm was seen in 13.33% in VAC group. Similar studies were conducted by Argenta *et al.*, Morykwas *et al.* & Joseph *et al.*, & these studies showed that VAC proved effective in shrinking of the diameter of the wound size and formation of healthy granulation tissue when compared to normal saline dressing methods. Russel *et al.* advocates that primary wound closure should be avoided in treatment of open Tibia fractures, whereas Veliskakis described primary internal fixation and primary wound closure gives good results.

There are several advantages of applying a Primary VAC to an open fracture and these include

1) Protects the wound from external environment and further bacterial contamination.
2) Absorbs the exudate from the wound and decreases local edema.
3) Prevents loss of fluid from the wound and thus provides a moist environment at the wound
4) Which favors collagen synthesis and epithelial proliferation.
5) Increases the local blood flow to the wound.
6) It considerably decreases the bacterial load of the wound and thus wound infection.
7) Maintains an acidic pH and low oxygen tension on the wound which promotes granulation tissue formation and angiogenesis.
8) Induces mechanical stretch on the cell cytoskeleton leading to the release of cytokines associated with wound healing.
9) VAC also reduce wound size, accelerates granulation tissue formation and lower the coverage complexity down the 'reconstructive ladder' when applied as a temporary dressing to acute open fractures.

Hence VAC can be applied after each debridement and irrigation until the wound is fit for a reconstructive procedure such as SSG or flap cover. VAC can be applied in a continuous or cyclical manner. The observation that intermittent cyclical treatment appears more effective than continuous therapy is interesting although the reasons for this are not fully understood. Two possible explanations were proposed by Philbeck *et al.* [16] They suggested that intermittent cycling results in rhythmic perfusion of the tissue which is maintained because the process of capillary auto regulation is not activated. They also suggested that as cells which are undergoing mitosis must go through a cycle of rest, cellular component production and division, constant stimulation may cause the cells to 'ignore' the stimulus and thus become ineffective. Intermittent stimulation allows the cells time to rest and prepare for the next cycle. For this reason it is suggested that cyclical negative pressure should be used clinically. The daily rental charges for a VAC machine and consumables are significant. This has discouraged many from using the system. However, there have been some reports showing that the increased healing times and downgrading of required operations correlate to decreased overall costs of care. The dressing should also enable larger wounds to be treated in the community with minimal nursing care impact. This would free up hospital beds permitting faster healing of operative patients and preventing waiting list buildup.

Conclusion

Following were the conclusions drawn from our study:

- Guistilo Anderson type 3 B open fractures were most commonly caused by road traffic accidents.
- Males were more prone for injury than females.
- The most common bone involved in this type of fracture is Tibia.
- Vacuum assisted closure therapy appears to be a viable adjunct for the treatment of open musculoskeletal injuries.
- Application of sub atmospheric pressure after the initial debridement to the wounds results in an increase in local functional blood perfusion, an accelerated rate of granulation tissue formation, and decrease in tissue bacterial levels.
- The granulation tissue formed was healthy and uniform.
- Soft tissue defects which lead to ugly and irregular surface was avoided by forming uniform granulation tissue and the defects were covered.

Although traditional soft tissue reconstruction may still be required to obtain adequate coverage, the use of this device appears to decrease their need overall.

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