Negative Pressure Wound Therapy (Vacuum-assisted Closure)

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Introduction:

Wound healing is a highly orchestrated procedure which commences with removal of debris and infection. Inflammation causes angiogenesis. Subsequently granulation tissue forms and healing progresses through wound contracture and maturation. Pressure, vascular insufficiency, diabetes, infection and prolonged immobilization. negatively affect healing. Debridement is the most important factor for healing of wound. It consists of removal of dead necrotic tissue, foreign bodies, sequestrum sinuses and loose implants. Negative pressure wound therapy with reticulated open cell foam (NPWT–ROCF), also called as vacuum assisted closure (VAC), has evolved as a beneficial adjunctive treatment modality for open wounds after high energy trauma and other wounds.

In 1989, Prof. Louis Argenta1-3 and Dr Michael Morykwas1,2 developed sub atmospheric pressure technique VAC. In 1997, they published papers Sub atmospheric pressure to wound to remove the exudate and debris, pus, edema fluid and bacteria from the wound.

Lawrence X Webb (2002) described the advantages of VAC as follows:

• Evacuation of wound edema, thereby significantly reducing wound volume, depth and surface area.

• Hastening and promoting the formation of hypervascular wound granulation.

• Rapid and complete incorporation of meshed split-thickness skin grafts (STSG).

• Being a closed system it lowers the likelihood of wound contamination by resistant hospital organisms. As the wound is sealed completely and not exposed to atmosphere, e.g. MRSA, septic complication from secondary nosocomial

infection. These dressing being in a completely closed environment act as a thermal insulator especially in burn victims.

• Economic advantages for the patient as well as the nursing load of dressing is reduced. This is because conventional dressing is changed daily either once or twice whereas VAC is changed every 48–72 hours. This also reduces patients' discomfort of repeated dressing. Wound is prepared faster for grafting.

– Moues et al (2004)6, examined the total cost of hospitalization, nursing and material of 54 wounds; concluded that the mean was in favor of NPWT.

– Schwein et al (2005)7 , performed a retrospective analysis of 2288 pressure ulcers to examine the clinical and economic benefits of NPWT. This study showed lower rates of general hospitalization, wound problem and emergency admission.

• Skin graft take is improved with shorter duration of hospital stay.

• Diabetic wounds with faster healing, reduced secondary amputation with NPWT–ROCF.

• Easy to transport the machine.

• Enables direct inspection of vacuum tube. This is allowing to assess the character and volume of drained fluid.

The fact is that NPWT–administered is an important part of treatment protocol of the most complex orthopedic wounds with no infection.

NPWT is an adjunctive to the management and is not a substitute for surgical debridement .

In our institute almost all wounds in patients are 'VAC' ed, to prevent cross nosocomial (hospital) infection.

Indications:

• Soft tissue trauma with or without underlying fractures is the best indication for NPWT–which provides temporary coverage for the wound reducing infection rate,

increasing rate of healing and granulation and thus preparing a healthy bed for skin grafting procedures

• Pressure skin grafts and to improve skin graft incorporation and also can be applied on donor site to epithelize it

• NPWT–can be applied on exposed bones, tendons and orthopedic implants. It may enhance tissue granulation over these substrates to allow closure

• Post-traumatic ulcers

• Diabetic foot with large wounds

• Wound after fasciotomy

• Infected wounds after debridement

• Postoperative infection

• Chronic osteomyelitis

• Surgical incisions that cannot close without tension

• Closed surgical incision with continued drainage especially if wound have serous drain on postoperative day four

• Postoperative hematoma in surgical wound

• Necrotizing fasciitis.

NPWT–: The Machine and Mechanism :

As a result of continuous research on the effect of subatmospheric pressure on open wounds, Kinetic Concepts, Inc. (KCI, San Antonio, TX) developed the KCI Vacuum Assisted Closure (VAC) system. It is an excellent machine.

It had a great disadvantage of cost in India. We developed and designed a new machine called GSK-VAC (vacuum assisted closure) in collaboration with of local instrument manufacturing M/s. Prasaditi Medical Equipments Pvt Ltd, Miraj.

It included a computerized unit with multiple software and automated timer programmed to intermittent mode. It also has an alarm system to indicate like leakage, blockage, timer fault and changes in vacuum pressure.

Machine :

The machine consists of following parts:

The vacuum therapy unit: It is a computerized panel with display and setting keys and pressure regulating device installed in it.

Canister: It is a container collecting the fluid drained from the wound. It is airtight.

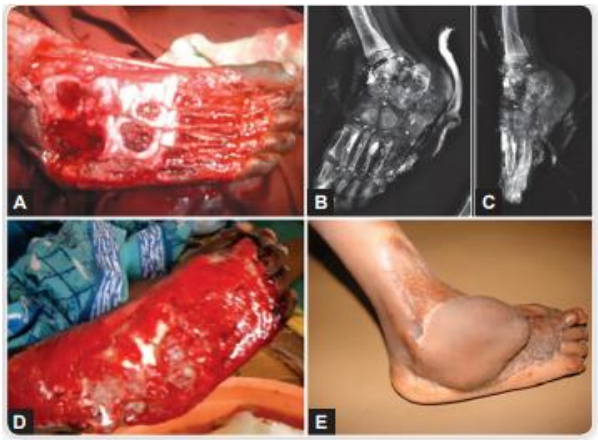
Connecting tubes: These are plastic tubes that connect canister to the vacuum device and the device to the wound.

Foam dressing: These are sterile open cell foam commercially available. They are gently placed on to the wounds in double layers. These reticulated medical grade foams are used as they are the most effective in transmitting mechanical forces across the wounds and provide an even distribution of negative pressure over the entire wound bed.

There are two types of foams available:

1. Polyurethane ether foam (PU): They have larger pore, lighter, easily collapsible and hydrophobic with a pore size of 400–600 nm, e.g. severe complex musculoskeletal injuries.

Figs 1A to G A 38-year-old female with Grade III B compound Lt. tibia fracture was initially debrided and VAC was applied with external fixator. Later on, after VAC removal Ilizarov external fixator application was done with STSG



Figs 2A to E A 28-year-old male with Rt. crush foot came with injury due to road traffic accident. After thorough debridement in emergency VAC was applied with 24 hours and removed after 48 hours. He was later on treated with free flap

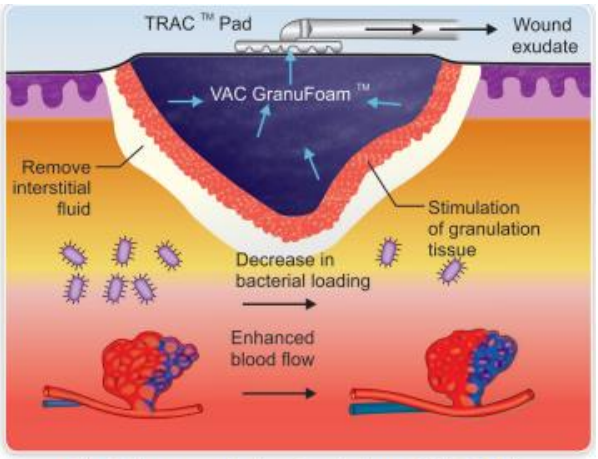


Fig. 4 Diagrammatic view of mechanism of NPWT–ROCF

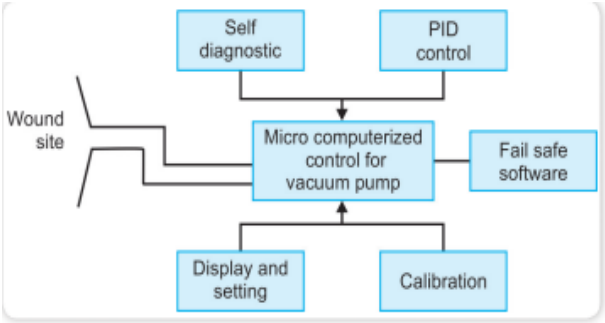


Fig. 3 New system-II analysis

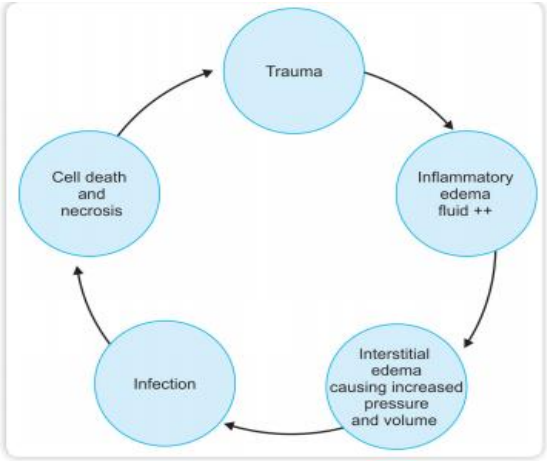


Fig. 5 Steps of application of NPWT–ROCF. All patient should undergo advanced trauma life support (ATLS). Once the patient is stabilized Gustilo and Anderson classification for the wound is to be done[11,12]

2. Polyvinyl alcohol foam (PVA): There are denser with smaller pores, requiring higher negative pressure to collapse and its hydrophilic (absorbs exudates) with a pore size of 250 nm. It is applied over the chronic and superficial wounds and nonhealing ulcers.

Fenestrated evacuation tube: Embedded into the foam dressing is a fenestrated evacuation tube which is noncollapsible and has side ports that allow communication of lumen to the space of reticulated foam.

Adhesive drapes: The surface of the foam dressing which is embedded with evacuation tube which is covered with an adhesive drape generally iodine drapes to seal it from the environment.

Dressings (Foam + evacuation tube + drapes) should be changed every 48–72 hours or earlier in infected wounds or wounds with a large amount of collection in canister. Other noninfected or drier wounds are continued with the dressing for at least 72 hours before it is changed.

Mechanism of Action:

There are currently two main theories regarding the mechanism of actions of NPWT–(Figs 4 and 5)

1. Macrostrain theory: Also called the mechanical theory.

2. Ilizarov effect.

Macrostrain theory: When the foam is placed on the wound exactly according to the shape of the wound and suction is applied with the help of the machine a visible stretch is seen on the foam which contracts over the wound. Several wrinkles are seen over the foam surface as it contracts as well as the canister shows contraction. Thus the entire wound undergoes evenly distributed suction effect thus removing the exudate all over.

Ilizarov effect: On application suction over the foam dressing, micro-distraction occurs over the cells. It has a stimulatory effect on cellular mitogenisis, angiogenesis and elaboration of growth factors. The principle of distraction osteogenesis is based on the same Ilizarov principle. There is an enhancement of the dynamics of microcirculation by active evacuation of excess interstitial fluid in the form of edema. There is a lowering of heightened capillary after load and a qualitative dilution of the contained micro contaminants, bacteria and proinflammatory cytokines thus promoting granulation tissue formation by facilitating cell migration and proliferation.

The tissues surrounding the wounds have a localized collection of interstitial or extra cellular fluid, which contains factors which are inhibitory to mitosis, protein synthesis and fibroblast collagen synthesis. An active withdrawal of this fluid removes the excess of third space wound fluid and its inhibitory factors. The active withdrawal also results in removal of wound debris.

The collection of extra cellular fluid compresses the micro vascular and lymphatic system. Thus there is decompression and there is increased vascularization, reduced venous after load and an increased delivery of oxygen and nutrients. These changes improve the rate of granulation tissue formation and concentration of growth factors within the wound. It is also known that successful wound healing correlates with bacterial count less than 105 organisms per gram tissue.10

Technique of application NPWT:

Wound Preparation:

After meticulous and thorough debridement and wound preparation and fracture stabilization the wound is ready for application of NPWT–ROCF. Debridement and stabilization are the two most important pre-requisites for VAC application. Before applying NPWT, hemostasis is confirmed and surrounding skin was made dry.

Foam Placement and Sealing:

For traumatic wounds polyurethane ether (PU) foams are used. The foam should be sterile and trimmed to appropriate size and geometry of each individual wound. Foam should never over flow over the skin. The edges of sponges to be rubbed to remove the lose particles. The foam is then gently placed onto the wound in double layers ensuring contact with all wound surfaces. In large wounds, foam to foam contact to be ensured between adjacent pieces, for even distribution of negative pressure (Figs 6 and 7)

Iodine impregnated adhesive drape is trimmed and placed over the limb to cover the foam dressing and additional 5–7 cm border of intact skin. Drape to be cut out into multiple pieces for easy handling. Excess drapes can be used to seal off difficult areas when necessary. Then the drape is pinched and a 2 cm hole is cut through the drape. The hole is made large enough to allow the removal of fluid or exudate.

The nipple should be placed with opening of the central disc of evacuation tube directly over the opening in drape. Only gentle pressure is to be applied to ensure a complete sealing off of the pad. The proximal end of the evacuation tube leads to the collection to the canister localized on the VAC machine into which the fluid is drawn when subatmospheric pressure was applied.

Thus an open wound was converted into a controlled closed wound.

Application of Negative Pressure:

The NPWT machine is adjusted to –125 mm Hg pressure and controlled pressure is uniformly applied all over the wound's surface. The pump can deliver either continuous or intermittent pressure ranging from –50 to –125 mm Hg (adjustable up to –240 mm Hg.) Intermittent mode is applied to all the wounds. It consisted of a 7 minute cycle, 5 minutes on and 2 minutes off while the negative pressure was maintained. Ideal pressure setting is –125 mm Hg but higher pressure up to –175 mm Hg may be required for larger wound as they produce a larger amount of exudate.

With continuous negative flow, there was increase in granulation by 63%, however when intermittently used the granulation increased by 103%.

Consider titrating the VAC pressure setting up by 25 mm Hg increments for the following conditions from KCI guidelines:

A B

Fig. 6 A) When the negative pressure is developed the sponge retracts as shown in the figure. Before applying –ve pressure.

B) After applying –ve pressure. Note wrinkles indicating contraction of sponges.

Fig. 7 GSK machine showing the canister

• Excessive drainage

• Large wound volume

• A tenuous seal.

The VAC pressure setting may be titrated down by 25 mm Hg for the following situations:

• Extremes of age

• Compromised nutrition

• Risk of excessive bleeding (e.g. patients on anticoagulation therapy)

• Circulatory compromise (e.g. peripheral vascular disease)

• Excessive granulation tissue growth

• Pain or discomfort not relieved by appropriate analgesia

• Periwound or wound bed ecchymosis.

First NPWT dressing in all patients should be changed after 48 hours and wound condition to be evaluated. Accordingly second look debridement may be carried out and again NPWT dressing applied. In cases of clear wounds subsequent

dressings can be changed after a minimal period of 72 hours while in infected wounds or severely contaminated wound dressing should be changed after every 48 hours. After each dressing the wound condition should be evaluated and further debridement if needed to be done. All the NPWT dressings are to be done under strict aseptic conditions. Evaluation was done for the amount of granulation tissue, i.e. abundant, inadequate, no granulation tissue and gross purulence (Figs 8 and 9).

Disadvantages of VAC–Webb, et al [13]:

• Skin rash due to irritation of sponge. This can be prevented by carefully cutting the sponge according to the shape of the wound and not fitting it overlap surrounding skin. It is self resolving.

• Bleeding at the granulation site during removal of VAC.

• Pain during exchange or removal of VAC dressing.

• Tearing of skin especially in flail adults.

Dangers of NPWT :

• Cut blood vessels should not be in the proximity of the wound

• Negative pressure applied continuously over wound causes pain to the patient

• NPWT should not be substitute of irrigation and debridement for infected wounds. As NPWT may not reduce bacterial load.

Complications :

• Do not apply on non debrided dirty wounds

• May cause bleeding if any cut vessel is in the vicinity of the wound on where NPWT is to be applied

• Pain may occur while removing the adhesive tape

• Retained sponge may lead to infection

• Be careful about Dehydration in children which may occurs due to suction of fluids from the wound

• Maceration of skin can occur if the foam overlaps the healthy skin. This occurs especially in the foot. To avoid maceration, take pieces of adhesive drape is applied around the edges of skin.

• Hematoma in surrounding tissue may occur

• In immune compromised individuals wound dehiscence can occur

• NPWT in patients on anticoagulants may cause excessive bleeding.

Fig. 8 A 50-year-old male with acetabulum fracture was operated with acetabular plating due to severe tension and swelling incisional VAC was applied and closure was done

Figs 9A to D A 25-year-old male operated for distal femur fracture. Had tense suturing so VAC was applied on incision and final suturing done after three days

Technical Complications :

• Leakage may occur in cases of power loss resulting in maceration and may cause infection and wound complications

• Poor sealing leading to loosening of drainage system.

- Rarely failure of parts of machine

Contraindication for NPWT :

• Necrotic tissue with eschar

• Exposed blood vessels, nerves, organs

• Undernourished patient

• Severe pain

• Malignant wound

• Nonenteric and unexplored fistulas

Range of pressure in VAC machine :

Standard: –125 mm Hg

Range: –125 to –200 mm Hg

Neonates: - 50 mm Hg

Children > 2 years: –75 to –125 mm Hg

Adults: –125 mm Hg.

How to Avoid Pain :

• Moisten the interface between sponge and wound

• Topical lidocaine without epinephrine on the wound surface.

Antibiotic Beads with Vacuum-assisted Closure :

It is a controversial topic as antibiotic is lost when fluid is drained, but it is followed in our institute as the 5 minutes interval of VAC exerts a beneficial effect.

Incisional Vacuum-assisted Closure (IVAC) :

Apply VAC on primary closure after surgery. NPWT is used in high risk surgical closure of wound.

• High energy tibial plateau fracture

• Calcaneal fracture

• Pilons fractures

• Acetabular fracture

• Amputed limbs in diabetics

• Previously irradiated tissue

• Morbidity obese patient

• Incisions in hip and knee replacement surgeries

Advantages of incisional vaccum assisted closure:

Vacuum-assisted closure system appears as a thermal insulation and prevention a loss of heat. This is a special important once in burns and physiological unstable and polytraumatized patients.

Vacuum-assisted Closure Instill :

Daniel Schlatterer14 has described instill irrigation technique is a gravity dependent filtration of the irrigant into the wound bed for approximately 30 seconds. This is followed by a short time period of no suction. This incubation phase is referred to as the dwell or hold time period. The solution reaches the wound bed after traversing the pressure foam dressing. This movement of irrigant is supported by the work of Labler and Trantz.15,16 Further studies are required to give definite recommendations. GSK-VAC instill is now available.

Conclusions:

NPWT (VAC) is a excellent adjuvant therapy. Wound debridement and stabilization are two most important prerequisite for NPWT application. VAC drains out edema fluid, enchances circulation and exuberant healthy granulation tissue is formed. It is used in almost all wounds and even surgical sutures in which post-operative infection is feared to occur.

NPWT has dramatically changed the management of wounds.

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