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Original Research Article

Vacuum assisted closure in the treatment of crush injuries of foot

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ABSTRACT

Objective: To study the outcome of Vacuum-assisted closure in the treatment of crush injuries of the foot using basic apparatus.
Materials and Methods: Our study was conducted from June 2015 to June 2018, involving 30 patients with crush injuries of the foot. All patients were treated with debridement and negative pressure therapy. The apparatus included sponge, cotton gauze pieces, feeding tube, adhesive impermeable cover which was attached to the vacuum system in the OT. The dressing was changed after every 3 days till wound healing or skin grafting.
Results: All cases were followed up every monthly upto 4 months and then every two months upto 2 years. All cases started showing signs of healing from eight weeks onwards.
Conclusion: Our study shows that VAC gives excellent results and improves the biology for healing. It is also an effective, reliable, safe and an easy procedure.

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1. Introduction

Crush injuries of the foot and ankle are often the result of high energy forces, commonly after RTA, industrial accidents and use of agricultural equipments. This poses a real challenge for the surgeons in planning the treatment as crush injuries often require extensive debridement and need bony reconstructions or arthrodesis with either bone grafts or soft tissue flaps or split thickness skin grafts.[1]

Negative pressure wound therapy (NPWT), was first introduced in North America by Argenta and Morykwas in 1997.[2,3] It is also called as micro deformational wound therapy(MDWT) and it's variant is Vacuum-assisted closure.[4]

In vacuum-assisted closure (VAC), to the wound's surface, a subatmospheric pressure is applied and sealed by a film dressing. This is then connected to a drain collection via a suction pump and a tube. VAC has revolutionised the way wounds are being managed as it decreases the number of days it takes for a wound to heal, less number of dressing changes are required and it can be easily applied. VAC can be applied for both acute and chronic wounds, even after failure of wound healing by primary intention. It is done till a healthy granulation tissue is developed over the wound which can then further be treated with skin flaps or grafts.[5]

The basic mechanism of action by how VAC works is that through the application of local subatmospheric pressure, there will be fluid drainage and this stimulates faster granulation tissue formation.

According to studies,[6–12] the principles to be applied in VAC are,

1. Conformation of the foam/sponge to the shape of the wound to achieve uniform local pressure.
2. Application of negative pressure results in collapse of foam cells, this helps in approximation of wounds by shrinking the surface of the wound. This mechanism

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helps in three times increase in migration of fibroblasts and twice the number of times decrease in cell death in comparison with a conventional dressing.

3. The additional advantage in using VAC is that studies have shown it is very effective in keeping the bacterial counts reduced till a bony coverage over the wound is achieved.[13–15]

The conventional VAC system that is usually used has four major components: 1. Sponge; 2. A cling film or semipermeable dressing; 3. connecting/suction tube; 4. Vacuum system. In some methods, a fluid collection canister with alarm sounds is also incorporated to alert in case of excess bleeding.[16]

Apart from crush injuries, VAC is used in acute and chronic wounds that arise from many different etiopathogenesis. These are managed by various methods according to their size and type. In comparison with VAC, these methods have not been found to be as cost effective.[17–19]

2. Materials and Methods

This study was conducted between June 2015 to June 2018, 30 patients with crush injuries of foot were included in this study. It was conducted with the ethical clearance from the institute. Written informed consent was taken from all the patients in the study.

There were a total 30 patients with an average age of 32 years(range 21-54 years), with 24 male and 6 female patients. All patients were admitted with crush injuries of the foot. 12 patients had associated comorbid conditions. Our exclusion criteria was wounds less than 5cm, infected wounds, osteomyelitis, patients less than 18 years old, associated fractures in the foot or leg.

After all the necessary investigations, all patients were taken up for debridement of the wound and VAC was applied. The apparatus included sponge, cotton gauze pieces, feeding tube, adhesive impermeable cover which was attached to the central suction unit in the OT. The dressing was changed after every 3 days till wound healing or skin grafting. Our method of applying VAC differs as the apparatus we used costs very less and appears to be as effective as a conventional VAC.

The basic apparatus which consists of a sponge, cling film and ryle's tube costs around Rs.200.

Start with shaving the hair around the border and then aggressively clean the wound and debride all necrotic tissue. Irrigate the wound with normal saline. Then we prepared the skin and appropriate sized sponges were cut according to the size and shape of the wound. Aggressive cleaning of the wound at each dressing change is imperative to decrease bacterial load and minimize odor.

Cut the foam to fit the size and shape of the wound, including tunnels and undermined areas. Ryle's tube cut at various level fast enough to cover the wound. Place the paraffin gauze on the wound surface with the tube on the wound. Keep the sponge over it. And cover it using the cling film. Cut the drape large enough to cover the sponge and 3-5 cm of surrounding healthy tissue with drape. Apply the drape beginning on one side of the sponge, towards the tube. Do not stretch the drape and do not compress the foam into the wound with drape. This helps minimize tension or shearing forces on periwound tissue. The tube was connected to the central suction unit. To ensure sealing of the dressing, a pressure bandage was applied to the wound together with manual compression to get rid of any air space. Standard pressure we keep in a VAC machine is 125 mmHg (range: 125-200mmgHg). Dressing is changed after every 3 days(on an average 5 times) until the wound is ready for STSG or flap coverage.

Fig. 1:

Follow up was done till wound healing. To document the progress of the wound, at each follow up, measurement and photos were taken. Main outcome measurements are : 1. Time taken for wound healing, and 2. Change(volume, width, depth) in the wound surface area, from initial injury to final follow up.

3. Results

The hospitalization period varied from 2 to 6 weeks. The follow-up period was till wound healing. Among the 30 crush injuries, 12 patients had comorbid conditions, 8 suffered from diabetes with 3 among them from morbid obesity and 3 patients had hypertension. All these cases were covered with skin grafts on an average 2.4 weeks (2-4 weeks range) and excellent reduction in the wound size and volume was observed (61% and 52% respectively).

Table 1: Score (grade) were based on Status and size of the wound

0	**Closed wound**	
1	1A	Skin or soft tissue defect (<10cm)
	1B	Skin or soft tissue defect (10cm-15cm)
	1C	Skin or soft tissue defect (>15cm)
2	Bone exposure, tendon injury/ Rupture (any one)	
3	Associated or Residual infection	

Fig. 2:

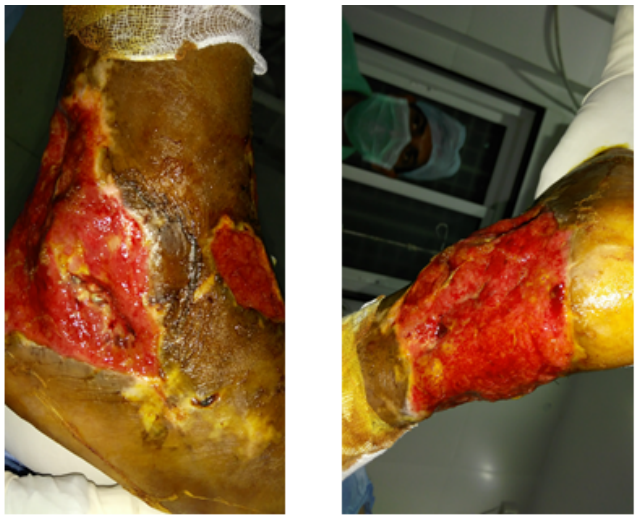

Fig. 3:

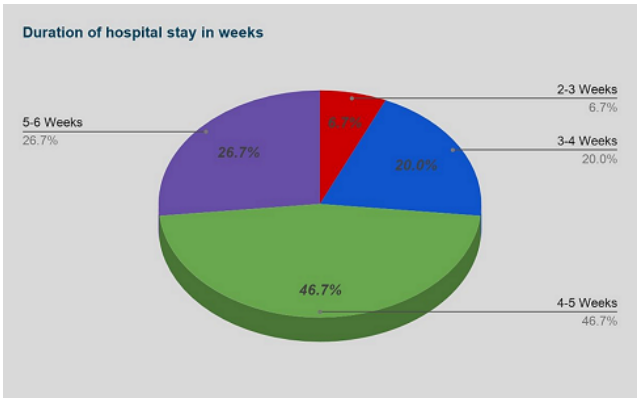

Fig. 4: Wound scoring system used in our study

Table 2: Total no of patients 30 (range 21-54) with mean age 31.6yrs

Age group of patients	No of patients	Percentage
20-30	16	53%
30-40	08	27%
40-50	06	20%

Table 3: Distribution of patients according to hospital stay in weeks with mean duration of Hospital stay 4.7 weeks

Duration of hospital stays (weeks)	Cases
2-3 weeks	02
3-4 weeks	06
4-5 weeks	14
5-6 weeks	08

4. Discussion

Since early 20th century, wounds have been treated using conventional dressing which act on the principle of mechanical forces which help in the tissue growth and new vessel formation.[20] During World War II, a new envelope method was introduced.[21] NPWT was already used by the Soviets by the end of last century.[22] This technique was brought into the forefront by Argenta and Morykwas.[17]

Table 4: General data distribution

Number of Patients	30
Male : female	24 : 6
Right side : left side	22 : 8
Mean age distribution	21-54 years
Total no of follow up period	4-6 weeks
Number of VAC Application	22.6 (Mean)

For acute wounds, many techniques have been used for treatment either by primary healing or by delayed wound closure.[23–26] In our study, crush injuries were debrided, cleaned and VAC was applied. Closure was successful without any complications.

Table 5: Detail of patients: Mean duration of VAC Application 22.6 days

S.No	Age	Sex	Site	Wound before vac	Wound after vac	Duration of vac application	Additional procedure	Major complication
1.	24	M	Dorsum of foot	18cm	7cm	15	STGS	Nil
2.	42	M	Medial aspect of ankle	21cm	8.2cm	24	Secondary sutures	Nil
3.	27	F	Lateral aspect of leg	28cm	11cm	18	Flap reconstructio n	Nil
4.	30	M	Plantar of foot	24cm	9.5cm	21	Secondary Suture	Nil
5.	38	M	Dorsum of foot	18cm	7.1cm	24	STSG	Nil
6.	28	M	Lateral aspect of ankle	24cm	9.4cm	18	Secondary Suture	Nil
7.	46	M	Plantar of foot	14cm	5.5cm	27	Flap Reconstructio n	Nil
8.	34	M	Dorsum of foot	22	8.6cm	24	STSG	Nil
9.	26	F	Medial aspect of foot and ankle	26cm	6.2cm	15	Secondary Suture	Nil
10.	29	M	Medial aspect to foot	24cm	9.3cm	15	Secondary Sutures	Nil
11.	47	M	Dorsum of foot	18cm	7cm	27	Flap Reconstructio n	Nil
12.	32	F	Anterior part of leg	14cm	5.4cm	24	Secondary Sutures	Nil
13.	21	M	Over medial aspect of leg	28cm	11cm	18	STGS	Nil
14.	49	M	Dorsum of foot	14cm	53cm	30	Flap Reconstructio n	Nil
15.	34	M	Posterior aspect of ankle	26cm	10.2cm	24	Secondary Sutures	Nil
16.	25	F	Plantar surface of foot	12cm	4.6cm	21	Secondary Suture	Nil
17.	41	M	Dorsum of foot	16cm	6cm	27	STGS	Nil
18.	48	M	Bilateral malleoli	26cm	10.2cm	30	STSG	Nil
19.	39	M	Over base of 4th and 5th metatarsal	12cm	4.6cm	24	Secondary Sutures	Nil
20.	40	M	Dorsum of foot	16cm	6cm	30	Flap Reconstructio n	Nil
21.	27	M	Over medial malleoli	14cm	5.5cm	21	Secondary Sutures	Nil
22.	23	M	Over lateral malleoli	12cm	4.7cm	18	STGS	Nil
23.	24	F	Medial aspect of foot	27cm	11cm	18	Secondary suture	Nil
24.	26	M	Dorsum of foot	18cm	7.2cm	21	Secondary suture	Nil
25.	37	M	Medial aspect of lower leg	29cm	11.5cm	27	STSG	Nil
26.	29	M	Lateral aspect of foot	27cm	11cm	24	STSG	Nil
27.	33	M	Dorsum of foot	18cm	7.2cm	24	Secondary Skin Closure	Nil
28.	30	M	Over lateral malleoli	24cm	9.5cm	21	STSG	Nil
29.	36	F	Dorsum of foot	12cm	4.7cm	21	Primary Skin Closure	Nil
30.	28	M	Dorsum of foot	14cm	5.5cm	27	Secondary Skin Closure	NilM

Key points

1. Negative Pressure wound Therapy/ VACis a good alternative/adjunct to standard wound care for difficult wounds.
1. Reconstructive procedures are reduced to an extent
1. The optimum pressure setting in our study for VAC is 25 mm of Hg logistic benefits of VAC

In multiple studies, VAC dressings were changed on an average of every 3-5 days.[27] In our study, we changed the VAC dressing after every 3 days, till the wound was ready for STSG. On an average, each patient's VAC dressing was changed for 5 times. After STSG, dressing was changed after 5 days.

In our study, the VAC pressure for wound healing was kept at 125mmHg. In studies conducted on animals, a sub-atmospheric pressure of approximately 125mmHg leads to increased blood flow, decrease in the local tissue edema and removal of excess fluid from the wound bed. This also aids in the bacteria removal from the wound. The study also observed that cyclical application with suction for 5 minutes alternating with suction off for 2 minutes leads to alteration in the cell's cytoskeleton leading to increased rate of cell division and formation of granulation tissue.[28]

In our study, 12 patients had associated comorbidities. 8 patients had Diabetes mellitus, 3 had morbid obesity and 3 had hypertension. Application of VAC dressings in these patients was at an average of 5 times, same as in the patients without morbidities. The average time taken for STSG to be done in these patients was 18 days. In several studies, where patients had an associated DM as comorbidity, it was noted that immediate application of VAC after removal of unhealthy and diseased tissue was very important. As it might lead to improper and irregular bed with cavities having hematoma or seroma collection resulting in poor take of skin graft.[21,22] Following the application of VAC, excellent take of skin graft was documented.[23]

In a study conducted by Eginton et al., VAC dressings lead to decrease in the wound volume(59% vs. 0%) and depth (49% vs 8%) significantly more when compared to conventional moist gauze dressings. Also VAC dressings helped in the decrease of overall wound dimensions including the width and length of the wound. They concluded that NPWT helps in the accelerated healing and closure of large foot wounds.[29] In our study, compared to the initial volume, there was a 61% decrease in the volume at the 5th change in VAC dressing, before doing skin grafting and 52% decrease in the depth of the wound. Following VAC, no complications were observed after STSG and excellent results were obtained.

The complications that were noted after application of VAC to the wound were:

1. Soldering of the surrounding skin was noted, where it might lead to increase in the wound size.
2. Patchy hypergranulation tissue formation leading to irregularity in the wound surface, with some areas with well developed granulation tissue and some areas devoid of it.
3. Discomfort to the patient while sleeping.
4. As our tube was connected to the central suction unit, risk of entry of pathogens present in the CSU. Further studies need to be done to evaluate the risk in using CSUs.
5. Furthermore, exact pressure cannot be regulated while using CSUs.

The advantages of VAC are that it drains the excess fluid from the wound bed, immobilizes the graft, enhances dermal perfusion and helps in angiogenesis. It provides a closed, healing, moist environment which also helps in control of odour and exudates. These merits are helpful in using VAC for complex acute wounds as it will also decrease the number of surgical procedures required. Hence, there is a tendency to use VAC more in acute than in chronic wounds.[24]

5. Conclusion

Even though VAC is a comparatively newer tool, it helps in the conversion of complex wounds into simpler wounds. It is a safe, easy and cheap procedure. Fewer and less painful dressing changes are required. STSG after VAC has a better take with less number of complications when compared to conventional dressing. Hence, VAC can be considered a better alternative to conventional dressing in the management of crush injuries of the foot.

6. Source of Funding

None.

7. Conflict of Interest

The author declares no conflict of interest.

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