Title

The effects of negative pressure wound therapy on wounds with cerebrospinal fluid leakages

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Objective: Negative pressure wound therapy (NPWT) has been widely used for a variety of wounds with good outcomes. However, it is contraindicated in the management of wounds with cerebrospinal fluid (CSF) leakages. The reason is the fear of a sudden shift of CSF fluid as a result of suction leading to brain herniation or coning. There is a paucity of data to either support or negate such claims. We aimed to determine the effect of NPWT in the management of patients with wounds with CSF leakages.
Method: This was a longitudinal prospective study of patients having wounds with CSF leakages managed with NPWT in our institute. Outcome measures evaluated were changes in the level of consciousness, Glasgow Coma Scale (GCS) score, length of hospital stay, mean effluent collected, time taken for the wounds to heal/close and complications related to NPWT.
Results: A total of 12 patients with wounds that had CSF leakage were managed with NPWT over two years. Of the patients, nine had wounds in communication with the brain, with three patients having spinal cord wounds. The average effluent collected on the first day of applying NPWT was 510ml, and by the third day this had fallen to approximately 200ml. The mean time taken for wounds to close was 12.3 days. There was no evidence of herniation nor any other morbidities or mortalities reported in any of our patients.
Conclusion: NPWT, as indicated in this series, had a beneficial effect in the management of wounds with CSF leakage. NPWT, once applied to the wound, caused a tamponade effect that resulted in stoppage of the leakage of the CSF and did not lead to suction of the fluid, as previously thought. The dressings ensured an airtight system, preventing communication between the wound and the external environment, thus reducing sepsis while awaiting definitive wound closure.
Declaration of interest: The authors have no conflict of interest to declare.

negative pressure wound therapy ● NPWT ● wounds with CSF leakage ● wound ● wound care ● wound healing

Negative pressure wound therapy (NPWT) was first described by Morykwas and Argenta in 1997, and has revolutionised the clinical management of wounds. Wounds that otherwise would not have healed are now managed with NPWT with good outcomes.[1,2] NPWT is thought to induce suction, which results in subatmospheric pressure around the wound that removes undesired metalloproteinases, bacteria and excessive moisture in the wound, allowing faster healing.[1–4] Cell deformation occurs as a result of negative pressure in the wound which, in turn, stimulates proliferation and angiogenesis.[3,4]

Wounds with cerebrospinal fluid (CSF) leakage can be a challenge to manage; in these cases, NPWT could represent an ideal dressing material due to its ability to remove excess fluid in the wound and ensure an airtight closure, protecting the wounds from maceration and contamination. However, the risk of a sudden change in intracranial pressure once the NPWT is applied could lead to brain herniation, coning, intracranial bleeds and even death. Recent studies by Kairinos et al. have contradicted the notion that NPWT works by creating a subatmospheric pressure environment around the wound.[5,6] Instead, their study suggested that once the NPWT is applied, the pressure in the wound increases to a greater extent than that in the vicinity, leading to a tamponade effect on the wound, theoretically eliminating the risk of herniation or coning. Therefore, in the current study, we sought to evaluate the clinical effect of NPWT on patients with wounds with CSF leakage.

Methods

This was a prospective longitudinal audit study on the effect of NPWT in the management of wounds with CSF leakages. The study was conducted at the Kenyatta National Hospital, a tertiary hospital in Kenya, between June 2015 and June 2018, and was approved by the local ethics and research committee.

The admission criteria for the study were patients with wounds with CSF leakage and who had a Glasgow Coma Scale (GCS) score of >10. Written and informed consent was obtained from the patient or next of kin as the case dictated, and this included consent for the publication of photographs. For minors, consent was obtained from the parents or next of kin.

Thorough surgical debridement was performed upon admission and a NPWT machine was then fixed to the

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wound and confirmed to be completely airtight. The machine was placed on the intermittent mode with a maximum negative pressure of 70mmHg. After fixation, patients were closely monitored in the intensive care unit or the high dependency care unit for at least 24 hours, for any signs of changes in the levels of consciousness, pulse or blood pressure that could be suggestive of a shift in intracranial pressure. The patients' level of consciousness was monitored using the GCS, which assesses motor response, speech and eye movements; a GCS of 15 is given for a fully conscious person, whereas a score of 3 reflects a patient who is in a deep coma. The effluent was monitored closely; any rapid increase in effluent would lead to cessation of the NPWT. The dressings were changed every 3–4 days until the wound was ready for closure. The time until the wound was ready for closure, as well as any complications, were noted.

Results

A total of 12 patients with CSF-leaking wounds were followed up during the study. The male:female ratio of the patients was 3:1. The age range of the patients was 4–65 years, with a mean age of 22.75 years (standard deviation (SD): 17.42 years, median: 23.50 years).

The average GCS score was 13.7 (SD: 0.44, median: 14) at the initiation of NPWT. The mean GCS scores on days 1, 2 and 3 were 13, 13.5 and 14, respectively.

The mean effluent volume collected on day 1 was 550ml, and was found to comprise a mixture of CSF and serous fluid. The mean effluent volumes collected on days 2, 5 and 8 were 430, 200 and 50ml, respectively. The average length of NPWT prior to wound closure was 12.33 days (SD: 5.63, median: 9.5). All patients were managed with NPWT to completion. Tables 1 and 2 summarise the characteristics of the patients during the study. There were no complications related to NPWT during the study.

Table 1. Patient characteristics in terms of injury

Patient number	Patient age, years	Sex	Diagnosis	Duration of NPWT (days)
1	4	F	Pygopagus	21
2	4	F	Pygopagus	21
3	6	F	Head injury with frontal orbital fractures	7
4	8	M	Post-RTA head injury with parietal occipital compound fractures	8
5	17	F	Post-gunshot spinal injury	14
6	35	M	Post-assault with occipital defect	15
7	26	M	Post-RTA parietal defect	20
8	65	M	Occipital skull defect, post tumor surgery	7
9	21	M	Post-RTA parietal defect	8
10	27	M	Occipital parietal defect	10
11	34	M	Post-assault frontal defect	9
12	26	M	Post-RTA parietal defect	8

F—female; M—male; NPWT—negative pressure wound therapy; RTA—road traffic accident

Table 2. Average Glasgow Coma Scale (GCS) score and mean effluent collected after initiation of negative pressure wound therapy (NPWT)

Day after starting NPWT	Mean GCS	Mean effluent collected, ml
0	13	–
1	13	550
2	13.5	430
3	14	200
4	14	50
5	14	50
6	14	45
7	14	45
8	14	45

Discussion

NPWT has revolutionised the management of wounds and led to a reduction in complications and the length of hospital stay.[1–3] NPWT has become an adjunct in the day-to-day management of wounds, with reconstructive surgeons using it as either a definitive wound closure tool or as a dressing prior to definitive wound closure. Its use has also spread to scar management and skin grafts, with good outcomes.[7,8] However, the use of NPWT in the management of wounds with CSF leakage, as well as in enterocutaneous fistulas, remains controversial as both are considered contraindications to NPWT.[9] There are limited data on the use of NPWT on wounds with CSF leakage.[10–14] Some studies have demonstrated disastrous effects with the use of NPWT on wounds with CSF leakage.[12–14] Most of these studies are, however, case reports that may not provide the required level of evidence in deciding upon whether or not to use NPWT on wounds with CSF leakage.

Our series suggests that NPWT can be of benefit in managing wounds with CSF leakage. All the patients in our study benefited from this management strategy, resulting in prompt wound closure with no complications. Furthermore, there was no clinical evidence of changes in intracranial pressure that could be attributed to the NPWT, such as brain herniation or coning, despite the fact that some patients were very young and with high volumes of CSF recorded (Figs 1–4). In this study, the wounds were able to attain a clean status with no bacterial growths after a short duration of NPWT (12 days), allowing for closure with flaps and skin grafts (Figs 5–7). In addition, there was a remarkable reduction in the effluent in all cases, casting doubt on the presumed mode of action of NPWT. Kairinos et al., in an unrelated experimental study, found pressure under NPWT to be much higher than that in the surrounding tissues that were not subjected to the suction.[5,6] This was irrespective of how the NPWT was applied, with maximum pressures being experienced

Fig 1. A conjoined twin with a raw wound that was leaking cerebrospinal fluid one day after surgery

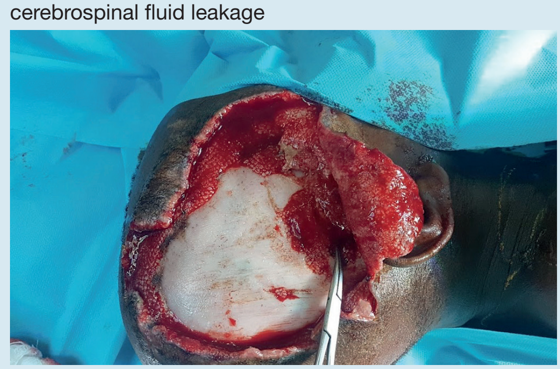
Fig 2. Negative pressure wound therapy applied to the wound shown in Fig 1

Fig 3. A well-granulated wound that is ready for closure after two changes of the negative pressure wound therapy dressings

Fig 4. Child with post head injury and cerebrospinal fluid leakage secondary to a motor vehicle accident

Fig 5. Negative pressure wound therapy was applied on the wound at a maximum negative pressure of 70mmHg

Fig 6. The wound was cleaned with artery forceps in communication with the brain at the point of cerebrospinal fluid leakage



close to the point of insertion with gradual lateral dissemination. One may therefore hypothesise that the reduction in the CSF effluent in our patients could be as a result of the tamponade effect caused by the NPWT on the wounds as opposed to the expected suction that would have caused an increase in effluent. If this is the case, then still critical is the NPWT pressures applied, since high pressures applied could still cause an increase in intracranial pressure leading to internal brain herniation or coning. Another observation in our series was the remarkable rate of achieving good granulation in our patients. All the wounds were ready for closure with either skin grafts or flaps within a short duration as a result of the good granulation achieved (Figs 4 and 6).How NPWT stimulates robust granulation is still not known. Several factors have been postulated, including stimulation of growth factors and hypoxia.[15–19] In a systematic review to determine the growth factor response to NPWT, Glass et al. demonstrated an increase in anti-inflammatory cytokines, systemic IL-10, and IL-6, in patients who were on NPWT.[20] They further demonstrated an increase in the expression of vascular endothelial growth factors, fibroblast growth factor 2, transforming growth factor-β

Fig 7. The wound was closed with a local flap and skin graft after two sessions of negative pressure wound therapy. No further cerebrospinal fluid leakage was noted

and platelet-derived growth factor, consistent with mechanoreceptor and chemoreceptor transduction in response to stress and hypoxia.

Limitations of the study

Shortcomings of our study included the fact that our patient sample size was small. Monitoring of our patients was only based on the clinical presentation, which could have been subjective as we were not able to monitor the intracranial pressure of our patients. Our patient population was limited to patients with good GCS, who ordinarily have not suffered from severe head injury, and as such have less cerebral oedema and increased intracranial pressure. There is thus a need for further studies to demonstrate not only the effect of pressure on wounds with CSF leakages, but also the optimum pressures to achieve good outcomes.

Conclusion

In conclusion, NPWT could have beneficial effects in patients with wounds that have CSF leakage. The technique in our series resulted in good wound granulation and reduction in CSF leakages, prompting for early wound closure. However, it needs to be used cautiously with close monitoring of the patient for any signs of deteriorating levels of consciousness. There is need for further studies to authoritatively investigate the use of NPWT on wounds with CSF leakage, given the conflicting results from previously published studies. JWC

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Reflective questions

- What are current theories on how negative pressure wound therapy (NPWT) works with respect to the pressure in and around the wound?
- How does NPWT affect tissue perfusion?
- Suggest how NPWT might work by stimulating hypoxia?