Research article

A retrospective, descriptive observational study on the use of negative pressure wound therapy with instillation and dwell time (NPWTi-d) in the management of infected diabetic foot ulcers

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ABSTRACT

Background Diabetic foot ulcers (DFU) are a major health concern globally due to their high risk of infection, amputation and associated healthcare burden. Negative pressure wound therapy with instillation and dwell time (NPWTi-d) has emerged as a promising adjunctive treatment for infected DFUs, especially when integrated into multidisciplinary care pathways.

Aim This study aimed to evaluate the clinical outcomes of NPWTi-d in the management of infected DFUs within a multidisciplinary team (MDT) setting in a tertiary hospital in Singapore.

Methods A retrospective, descriptive observational study was conducted involving 50 patients with infected DFUs treated with NPWTi-d (V.A.C. Veraflo™) following surgical debridement between January 2021 and June 2022. Patient demographics, wound characteristics, treatment timelines, and outcomes were extracted from a chronic wound registry and electronic medical records. Descriptive statistical analysis was performed using JMP® software.

Results Of the 50 patients included, 90% (n=45) achieved complete wound healing. The majority (88%, n=40) underwent successful closure via reconstructive surgery, while none required major amputation. The median length of stay was 20 days, and the mean number of operative visits was four. More than half of the patients (52%, n=26) underwent minor amputations, primarily ray amputations and toe disarticulations.

Conclusion NPWTi-d, when applied post-debridement and supported by MDT care, appears to be effective in achieving high wound healing rates and facilitating limb preservation in patients with infected DFU.

Implications for clinical practice These findings support the integration of NPWTi-d into MDT pathways for early and effective management of infected DFU. Further prospective comparative trials are warranted.

Keywords diabetic foot ulcers, negative pressure wound therapy, instillation therapy, lower extremity amputation, multidisciplinary team

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KEY MESSAGE

- This retrospective observational study explored the use of NPWTi-d to promote wound healing and support limb salvage in patients with infected diabetic foot ulcers (DFU).
- The study aimed to evaluate clinical outcomes associated with NPWTi-d when integrated into a multidisciplinary care approach for managing infected DFU.
- Findings demonstrated a 90% wound healing rate, with 88% of wounds closed through reconstructive surgery and no major amputations reported, indicating promising clinical outcomes.

INTRODUCTION

A diabetic foot ulcer (DFU) is a serious complication of diabetes that significantly impairs an individual's ability to perform daily activities and diminishes overall quality of life.[1] DFU also contributes substantially to both the clinical and economic burden on healthcare systems and is associated with increased mortality.[2-3] An estimated 85% of individuals with DFUs experience complications, such as gangrene or infection, often resulting in some form of amputation.[4] Bakker et al[5] reported that a limb is lost every 20 seconds due to diabetes-related complications, while Zhang et al[6] noted that 8–51% of individuals are at risk for a second amputation within five years of their first.

In recent years, negative pressure wound therapy with instillation and dwell time (NPWTi-d) has gained attention and is increasingly incorporated into wound care protocols.[7-8]

NPWTi-d combines cycles of negative pressure with the intermittent instillation and removal of a topical solution, delivered with a predetermined dwell time.[7] According to Kim et al[9], the instillation process facilitates bacterial clearance and removal of wound debris, while also delivering nutrients and growth factors that promote granulation and tissue regeneration. These effects contribute to accelerated wound bed preparation and earlier wound closure.[9-10] Several studies have reported the effectiveness of NPWTi-d in managing infected and complex wounds across diverse clinical settings.[11-14]

In the author's institution, NPWTi-d has been adopted as a first-line adjunctive treatment immediately following debridement for infected DFU. However, limited data exist regarding its clinical outcomes in the local context. This study therefore aimed to examine the outcomes of NPWTi-d in the management of infected DFU. The primary outcome was the rate of complete wound healing. Secondary outcomes included time to healing, number of operative interventions, length of hospital stay (LOS), need for plastic or reconstructive surgery and rates of minor and major amputation.

The study was conducted at a 1000-bed public hospital in northeastern Singapore, which began operations in August 2018. To provide comprehensive care for patients with diabetic foot complications, the hospital established a dedicated Diabetic Limb Salvage (DLS) clinic in 2019. The DLS clinic focuses on timely intervention for active DFU to minimise the risk of major amputations. Patients typically present with urgent conditions requiring revascularisation or surgical debridement of infected or necrotic tissue. Management of these cases is carried out by a multidisciplinary team (MDT) comprising orthopaedic and plastic surgeons, interventional radiologists, specialty care nurses, and podiatrists.

METHODS

This was a cross-sectional, retrospective, descriptive observational study involving patients with infected DFU who underwent NPWTi-d treatment following surgical debridement. All patients who were reviewed by the MDT and who met the inclusion criteria were enrolled. The inclusion criteria were: 1) Patients ≥ 18 years old; 2) Inpatient admission under the MDT; 3) Presence of an infected DFU that requiring surgical debridement and systematic antibiotic therapy; 4) Suitable to receive NPWTi-d intraoperatively. Patients with ulcers of other aetiologies and wounds for which the use of NPWTi-d is contraindicated were excluded. Patient data were obtained from the institutional chronic wound registry, which contains information from patients who had provided consent for their clinical data and treatment outcomes to be used for research purposes.

On admission to the hospital, all patients received intravenous antibiotics as part of their initial treatment. The choice of antibiotics was based on the clinical judgment of the MDT and was modified as necessary once the susceptibility results from the wound cultures taken during surgical debridement became available.

Surgical debridement was performed in the operating theatre, followed immediately by the application of NPWTi-d by the orthopedic surgeon. MDT members had received standardised training in the NPWTi-d technique to ensure consistent application. NPWTi-d was administered using the V.A.C. Veraflo™ (3M Healthcare, St. Paul, MN, USA), with Granudacyn™ (Mölnlycke Health Care, Gothenburg, Sweden) as the instillation solution. The solution volume was determined using the system's 'Fill Assist' function, based on foam saturation for each wound. The protocol included a 10-minute dwell time, followed by negative pressure set at -125mmHg every three hours.

All wounds were inspected every three to four days during the MDT rounds. Treatment decisions, such as continuation of NPWTi-d or progression to surgical closure via reconstructive procedures, were based on clinical evaluation of the wound bed condition, such as the presence of healthy granulation tissue, signs of infection and contraction of wound edges. If the wound bed was not suitable for closure, NPWTi-d was reapplied without further surgical debridement. If the wound exhibited sufficient progression, early reconstructive closure (such as graft or flap) was performed to expedite wound healing. Reapplication of NPWTi-d during the ward stay was undertaken by trained specialty care nurse or podiatrist in the MDT.

Data were collected retrospectively from electronic medical records using a structured data collection form by the author. Information was subsequently transferred into an Excel spreadsheet and cross-validated by an independent research intern. All data were anonymised, and each patient was assigned a unique identifier to protect confidentiality. Data analysis was performed using the JMP® statistical software package (SAS Institute Inc, USA). Descriptive statistics, including measures such as mean, median and standard deviation (SD), were used to summarise the data.

The number of operative visits was defined as the number of debridement or closure procedures done in the operating theatre during the hospitalisation period. The length of stay was the total number of days the patient spent in the hospital from the date of admission to the date of discharge. Minor amputation refers to the surgical removal of a body part at or below the level of the ankle joint, while major amputation is defined as the surgical removal of a body part located above the ankle joint.[15.] A wound was considered to be healed when there was complete epithelisation with no drainage and without the need for additional dressing.[16]

To access hospital records, the author was appointed as a research intern by the institution. Informed consent procedures were already in place for all patients referred to the MDT clinic, including consent for the use of their anonymised data in future research.

RESULTS

Retrospective data collected from January 2021 to June 2022 were included in the analysis. Of the 84 patients who received NPWTi-d therapy documented in the chronic wound registry, 50 met the study's inclusion criteria and were included in the final analysis. The remaining 34 patients were excluded because they received instillation solutions other than Granudacyn™.

Demographic variables including gender, age and ethnicity were analysed. The majority of the patients were male and over the age of 60. Notably, there was a higher proportion of patients of Indian ethnicity compared to the racial distribution

of the Singapore population.[17] All patients presented with multiple co-morbidities, in addition to diabetes. Slightly more than half of the patients had three or more co-morbidities (n=28, 56%). Table 1 summarises the demographics of the sample.

Among the 50 patients analysed, 90% (n=45) achieved complete wound healing. Nearly half of the wounds (49%, n=22) healed within eight weeks or less. The majority of patients (88%, n=40) underwent definitive closure via reconstructive procedures such as skin grafts or flap coverage. The remaining five patients (12%) achieved wound healing through delayed primary closure.

The average number of operative visits per patient, including debridements and closure procedures, was four. The mean length of hospital stay was 23 days, with a median stay of 20 days (IQR: 9–27; 95% CI: 17.91–29.28). Minor amputations were performed in 52% of patients (n=26), primarily involving ray amputations and toe disarticulations. Importantly, no patients in this cohort required a major amputation. Table 2 summarises the frequency distribution of the clinical outcomes examined in the study.

DISCUSSION

This retrospective, descriptive observational study aimed to evaluate the use of NPWTi-d in the management of infected DFU within a MDT setting. A total of 50 patients who received NPWTi-d following initial surgical debridement were included in the analysis. The study sample comprised more males than females, which is consistent with existing evidence reporting a higher prevalence of DFU among men compared to women.[6,18-19] Vanherwegen et al[20] suggested that this gender disparity may be attributed to a poorer vascular condition in men, potentially related to a higher prevalence of smoking. Yazdanpanah et al[21] proposed that men typically engage in more physically demanding activities, which may increase foot trauma and exposure to high plantar pressures, contributing to a greater risk of ulceration.

Table 1. Demographics

Variable	n	%
Gender		
Male	36	72
Female	14	28
Age		
60 years or younger	16	32
60 years or older	34	68
Ethnicity		
Chinese	22	44
Malay	15	15
Indian	13	13
Co-morbidities		
Hypertension	38	76
Hyperlipidaemia	36	72
Peripheral artery disease	20	40
Ischaemic heart disease	17	34
Chronic kidney disease	7	14
End stage renal failure (on haemodialysis)	5	10
3 or more co-morbidities	28	56

This study found that the majority of patients were aged 60 years and above, with a disproportionately higher representation of Malay and Indian ethnicities compared to the general ethnic distribution in Singapore.[17] These findings are consistent with a study by Loo et al[22], which also reported a higher incidence of DFU among the older adults and individuals of Malay and Indian ethnicities. In addition, previous authors have also highlighted the high prevalence of DFU in these specific ethnicity groups.[19,23-26] Riandini et al[19] suggested that these findings may be attributed to the differences in health beliefs, health literacy, socioeconomic status, and access to healthcare. Shaw et al[27] further highlighted that delays in seeking medical attention among these populations may be influenced by cultural, traditional or intergenerational beliefs. For instance, some patients may rely on traditional remedies to treat DFU instead of consulting a medical professional. According to Ge et al[33], a high portion of patients who did not adhere to prescribed treatment for a DFU were generally younger males of Malay or Indian ethnicity and were likely to be ex-smokers or current smokers. Despite having fewer comorbidities, they have poorer DM control and higher HbA1c levels. Although the current study did not explore the influence of cultural practices or treatment-seeking behaviours, the findings underscore the importance of culturally sensitive healthcare interventions. Future research should explore how traditional beliefs and healthcare-seeking behaviours among different ethnic groups may impact DFU.

The findings from this study support the clinical utility of NPWTi-d in facilitating wound healing in infected DFUs. A complete wound healing rate of 90% was observed, with 88% of patients achieving closure through reconstructive

Table 2. Frequency distribution of the clinical outcomes

Outcome	Number of patients (n=50)	Percentage (%)
Wound healing status		
Wound healed	45	90
Wound unhealed	5	10
Time to wound healing (n=45)		
1–4 weeks	5	11
5–8 weeks	17	38
9–12 weeks	9	20
13–16 weeks	7	15.5
16 weeks or more	7	15.5
Number of operative visits		
1	4	8
2	16	32
3	12	24
4	10	20
5 or more	8	16
Length of stay (LOS)		
7 days or less	10	20
8–14 days	7	14
15–21 days	12	24
22–28 days	11	22
28 days or more	10	20
Amputation		
Minor	26	52
Major	0	0

procedures. These outcomes are comparable to findings reported in prior studies. For instance, Brinkert et al[12] demonstrated a 98% closure rate through reconstructive surgery using NPWTi-d, while Malviya et al[28] reported a 100% closure rate. A systematic review by Kanapathy et al[7] further supports these results, with a pooled wound closure rate of 93.65%. Collectively, these findings reinforce the role of NPWTi-d in preparing the wound bed for timely and effective closure.

The study indicated that a substantial proportion of the wounds (49%, n=22), achieved healing within 8 weeks or less. This finding suggests the potential effectiveness of NPWTi-d in accelerating wound closure. The study also highlighted that the average LOS for patients was 23 days, with a median of 20 days. In addition, the majority of patients required three or more operative interventions to achieve wound closure. However, since there was no comparison group in the study, it is difficult to draw direct inferences about the positive effects of NPWTi-d on these outcomes and the potential cost-savings of the NPWTi-d treatment. Moreover, patient-related factors, such as the presence of multiple co-morbidities and the characteristics of the wound itself, can significantly impact LOS and the number of operative interventions.[29] Therefore, further research is required to explore the comparative clinical and cost-effectiveness of NPWTi-d compared to different treatment approaches.

More than half of the patients (52%, n=26) underwent minor amputation procedures, predominantly ray amputations and toe disarticulations. This approach aims to remove infected or non-healing tissue while preserving as much limb function as possible.[30] The absence of major amputations among the study participants suggests that the utilisation of NPWTi-d, in combination with surgical interventions and other treatments, contributed to successful limb salvage and avoided the need for more extensive amputations. By preserving the limb and therefore maintaining mobility, individuals have a higher chance of maintaining independence, social engagement, and overall well-being.[31]

To the best of the author's knowledge, this is the first study in Singapore to specifically evaluate the use of NPWTi-d in the management of infected DFU within a MDT setting. While definitive conclusions regarding the efficacy of NPWTi-d cannot be drawn due to the retrospective nature of the study and absence of a control group, the findings provide important insights and contribute to the limited body of local research on this topic.

The primary limitations of the study are associated with the retrospective design. Retrospective studies are susceptible to selection bias,[32] as they may include only a subset of patients with complete medical records or those who were more likely to benefit from the intervention. Additionally, the study's sample was small and selected from a specific MDT setting in a single healthcare institution, which may not be representative of the general DFU patient populations in other settings. This limits the generalisability of the study findings to different healthcare contexts and patient cohorts, as variations in treatment protocols, healthcare resources, and patient demographics could influence the results.

Furthermore, the absence of a comparison group limits the ability to determine whether the observed outcomes were solely attributable to NPWTi-d or if they could be influenced by other factors. While this may have an impact on the strength of the study, the focus of this study was to explore the outcomes and characteristics associated with NPWTi-d in order to provide a basis for subsequent prospective studies.

Despite these limitations, the study offers valuable context-specific evidence that can inform local clinical practice. Future research incorporating prospective comparative trials, such as RCT, involving multiple healthcare institutions with a larger sample size, and assessing long-term clinical and economic outcomes would enhance the generalisability and strength of evidence on the use of NPWTi-d in managing infected DFU. In addition, cost-effectiveness analyses are needed to determine potential cost savings associated with reduced hospitalisations, reduced complications such as amputations and improved wound healing rates.

CONCLUSION

This study demonstrates that NPWTi-d, when used as part of a multidisciplinary approach, is associated with high wound healing rates and successful limb preservation in patients with infected DFU. The majority of wounds were closed surgically, with no major amputations recorded. These results reinforce the potential of NPWTi-d as an effective adjunct in wound bed preparation and closure. Further prospective research is warranted to establish comparative effectiveness, assess patient-centred outcomes, and inform cost-benefit considerations in wider clinical practice.

IMPLICATIONS FOR CLINICAL PRACTICE

- NPWTi-d can be effectively integrated into MDT care pathways to optimise wound bed preparation and reduce the need for major amputation.
- Early surgical debridement followed by NPWTi-d may accelerate healing and reduce hospital length of stay.
- Standardised training and protocol use across teams ensure consistent and reproducible outcomes when applying NPWTi-d.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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