

Negative pressure wound therapy with instillation and dwell time (NPWTi-d) with V. A. C. VeraFlo in traumatic, surgical, and chronic wounds—A helpful tool for decontamination and to prepare successful reconstruction

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Abstract

For nearly two decades, Negative Pressure Wound Therapy (NPWT) has been used for temporary wound coverage as well as wound bed preparation. The addition of instillation and dwell time as an adjunct to NPWT (NPWTi-d) enables wound bed cleaning and improved wound bed granulation. Thirty patients with different types of colonised wounds (traumatic, surgical, and chronic) were treated with NPWTi-d using saline for instillation. Patient data, microbiological data and wound characteristics were collected and analysed. Endpoints were bacterial decontamination (count and type), effect on wound bed granulation, and successful reconstruction. Additionally, subgroup analyses for traumatic, surgical, and chronic wounds as well as patients pretreated with conventional NPWT or isolated gram-positive or negative germs were performed. NPWTi-d was applied on average for 13 days with a total hospitalisation time of 51 days. After NPWTi-d, decontaminated wounds were detected in 23% of cases. The number of different bacteria as well as bacterial count could be significantly reduced from 2.38 to 1.16 and 3.9 to 1.3, respectively. This was similar for all subgroups except surgical wounds, in which NPWTi-d did not lead to a significant reduction of the bacterial count. NPWTi-d resulted in a significant stimulation of granulation tissue. Successful reconstruction was achieved in 90% of cases. NPWTi-d enabled wound pre-conditioning by powerfully reducing or decontaminating the bacterial load and spectrum in most of the wounds. The wound bed integrity was re-established to prepare successful reconstruction.

Yannick F. Diehm and Julia Loew contributed equally.

[Correction added on 7 November 2020, after first online publication: Projekt Deal funding statement has been added.]

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KEYWORDS

bacterial colonisation, dwell time, NPWTi-d, wounds, instillation, negative pressure wound therapy, reconstruction

1 | INTRODUCTION

Complex wounds derive their definition mainly from the loss of wound bed integrity, affection of multiple tissue layers, local inflammation, bacterial colonisation as well as low nutritional supply, and reduced vascularity.¹ In the case of chronification, loss of quality of life results from limited function, pain, smell, shame, and related limited social interactions.^{2,3}

Negative Pressure Wound Therapy (NPWT) has been introduced in the late 1990's and provides a sterile, temporary coverage with additional active promotion to stabilise the wound bed, increase local perfusion, and stimulate the formation of granulation tissue.^{4,5} Intermittent wound rinsing followed by NPWT may have the power to keep a moist wound environment and provide mechanical rinsing for bacterial decontamination. In addition, it may advance the wound bed integrity by improved stimulation of granulation tissue thus adding another active tool to NPWT.⁶ The addition of instillation and dwell time offers active local wound irrigation with the goal of wound preparation for subsequent reconstruction. Negative Pressure Wound Therapy with Instillation and Dwell Time (NPWTi-d) has been successfully implemented for indications like traumatic, surgical and diabetic wounds or ulcers and osteomyelitis with little-to-none side effects.⁷ For instillation, balanced solutions (eg, saline, Ringer's Lactate) or active anti-infective solutions (eg, polyhexanide, hypochlorous solution) have been used so far.^{7,8} However, evidence demonstrating superiority of any solution is limited.⁹⁻¹¹ Additionally, data regarding the use of NPWTi-d analysed separately for different wound types is sparse.

The aim of this study was to define the effect of NPWTi-d on complex wounds of traumatic, surgical, or chronic origin. This study addresses wound bed integrity and decontamination by reducing the spectrum of bacteria and/or the bacterial load and its effect on the wound bed. Secondary, we aimed to define the individual effect of NPWTi-d for different wound types or wounds with specific microbiological characteristics in a subgroup analysis.

2 | PATIENTS AND METHODS

Thirty patients with complex wounds were treated according to a standardised protocol with NPWTi-d (V. A. C. VeraFlo, KCI Medizinprodukte GmbH,

Key Messages

- wounds with high risk for contamination and colonisation require individual tools and strategies to prepare and promote wound healing. Negative pressure wound therapy with instillation and dwell time (NPWTi-d) can be a useful tool in the plastic surgeons' armamentarium for reducing the bacterial load and promoting wound bed integrity. We investigated the effect of NPWTi-d on bacterial colonisation and wound bed integrity as well as wound closure for traumatic, surgical, and chronic wounds
- NPWTi-d led to a significant reduction of the bacterial spectrum and bacterial count. Furthermore, formation of granulation tissue was successfully induced facilitating successful reconstruction in 90% of cases
- NPWTi-d enabled optimised wound preconditioning by restoring the wound bed integrity and bacterial decontamination or reduction of load and spectrum. However, full justification for it in the literature is still lacking besides increasing evidence

Wiesbaden, Germany) (Table 1) and included in this retrospective study. The therapeutic and reconstructive goal of this protocol was to prepare the wound bed by

TABLE 1 NPWTi-d standardised device settings

NPWTi-d System	V.A.C. VeraFlo (KCI Medizinprodukte GmbH, Wiesbaden, Germany)
Negative pressure and Therapy settings	-125 mm Hg; continuous, intensity: low
NPWT-cycle duration	210 min
Instillation solution	Saline
Instillation volume (by "Fill Assist") (mean)	70 mL
Dwell time	10 min

reduction of the bacterial load and spectrum as well as by promoting stabilisation of the wound bed to enable wound closure. The study was in accordance with the local ethics committee and the declaration of Helsinki.

With reference to the definition of colonisation as the presence of multiplying bacteria in a wound with no patient immune response, inclusion criteria for this study were:

Patients suffering from wounds which had a high risk for bacterial colonisation due to their chronic or traumatic character or due to factors like comorbidities or long and complex surgeries. Additionally, patients with wounds defined by a wound bed with loss of cellular integrity, wounds with reduced vascularity due to a compromised perfusion because of intrinsic factors or wounds without healing tendency over the time of at least 6 weeks were included.

Patients with malignancies, untreated osteomyelitis, wounds without sufficient surgical debridement and wounds with exposed vasculature or nerves were excluded. Antibiotics were used according to the responsible board-certified plastic surgeon and were not an additional inclusion or exclusion criterion of this study, as the factor NPWTi-d was chosen as the sole interventional parameter.

Patient demographics and relevant comorbidities (eg, cardiovascular diseases, diabetes mellitus, venous insufficiencies, or adipositas) were extracted.

2.1 | Standardised NPWTi-d protocol

The standardised treatment algorithm included radical surgical debridement with tissue biopsies for microbiological analyses prior to starting with the first cycle of NPWTi-d. Tissue biopsies were taken and used for analysis before the initiation of NPWTi-d and at each dressing change. NPWTi-d was applied in accordance with the manufacturer's guidelines and the consensus guidelines published in 2013.⁸ NPWTi-d device settings are listed in Table 1.

The instillation volume was based on the defect size and controlled and determined with the "Fill Assist" software tool, resulting in a mean of 70 mL. Dwell time was set to 10 minutes, followed by a 210-minute negative pressure period. Negative pressure was set to "continuous mode," with intensity set to "low." Dressing changes were performed after 2 to 5 days, and 2 changes were initially scheduled. All wounds were intended to be treated for 14 days. If the therapeutic aim (decontamination, wound bed integrity) was achieved within 14 days or earlier, NPWTi-d was discontinued ($n = 25$), and final wound closure was performed as described below. If NPWTi-d showed promising results after 14 days but further improvements were expected through an additional NPWTi-d cycle, NPWTi-d was continued ($n = 5$).

In 15 patients, wounds were initially treated with conventional NPWT prior to the initiation of NPWTi-d. If conventional NPWT failed to improve wound bed integrity or bacterial load, NPWTi-d was applied in these patients.

All cases underwent photo documentation and clinical measurements of the wound size before NPWTi-d application and at each dressing change. Final wound closure was performed, if wounds were assessed to be clinically ready, by suture, split-thickness skin grafting or flap surgery through a board-certified plastic surgeon.

Outcome measures included analysis of patients' charts for risk factors and previous therapies, defect genesis (traumatic, postsurgical, chronic), wound characteristics, granulation tissue formation, successful wound coverage, and microbiological wound characteristics (bacterial load and spectrum). Tissue biopsies were compared before and after NPWTi-d treatment. Bacterial spectrum was analysed by number of different bacteria (NDB) and the semi-quantitative measurement of bacterial count (BC). BC was categorised by experienced microbiologists with categories 1 (few), 2 (moderate), 3 (several) and 4 (numerous) of germs. While all wounds have been exposed for a certain amount of time, wounds were anticipated to be colonised. This means that multiplying bacteria were present on the surface of a wound without a patient immune response. If no germs could be detected in a previously colonised wound after NPWTi-d, wounds were considered as "decontaminated," as the goal of the therapy was a complete removal of wound germs.

Outcomes were analysed for all wound types (AW). Furthermore, a subgroup analysis was performed for wounds characterised as traumatic (TW), surgical, (SW) or chronic (CW) to achieve separate results. Patients who received conventional NPWT prior to NPWTi-d were analysed in their own subgroup (cNPWT). To further assess the influence of bacterial types on the effect of NPWTi-d, additional subgroup analyses were performed for wounds with only gram-positive (gram+) or gram-negative (gram-) germs.

Statistical analysis of bacterial colonisation was performed by means of Statistical Package for Social Science SPSS, Version 18.0 (SPSS Inc., Chicago) with a Wilcoxon test for related samples and a significance level of $P < .05$.

3 | RESULTS

3.1 | Patient characteristics

Of all included wounds (AW = 30), the type of wounds was traumatic (TW; 40%/ $n = 12$; gunshot, cut, crush

injury, décollement), postoperative wound dehiscence (SW; 33%/n = 10), and chronic (CW; 27%/n = 8; diabetic wounds, ulcers, decubiti). Out of all wounds (n = 30), 15 patients were pretreated with conventional NPWT before the initiation of NPWTi-d (subgroup cNPWT). Ten patients had isolated gram-positive (subgroup gram+), 9 patients gram-negative (subgroup gram-) germs. The average age of all patients was 55 years (18-80) and 53 (29-70), 54 (26-80), and 51 (18-65) years for TW, SW and CW, respectively. Twenty-one patients were male (70%), 9 female (30%) (TW 83:17%/n = 10:2; SW 60:40%/n = 6:4; CW 62.5:37.5%/n = 5:3). Wounds were predominantly located at the lower extremity (AW 56%/n = 17; TW 92%/n = 11; SW 40%/n = 4; CW 25%/n = 2), followed by the trunk in 37% (n = 11) (TW 0%/n = 0; SW 50%/n = 5; CW 75%/n = 6) and upper extremity in 7% (n = 2) (TW 8%/n = 1; SW 10%/n = 1; CW 0%/n = 0). The average wound size was 179 cm² (range: 16-1600 cm²; TW = 134 cm²; SW = 179 cm²; CW = 148 cm²). Sixty-three percentage of all patients (n = 19) reported at least 2 comorbidities; 23% (n = 7) a long-term tobacco abuse (TW 16%/n = 2; SW 30%/n = 3; CW 25%/n = 2). Patients with surgical wounds had the following preceding operations: wound dehiscence after osteosynthetic treatment of a hand fracture (n = 1), after ostesynthesis of the tibia (n = 2), after a knee endoprosthesis (n = 1), after a vein stripping procedure of the leg (n = 1), after breast implant insertion (n = 1), after spine surgery (n = 2), and after abdominal surgery (n = 2).

For the other subgroups, mean age was 50 (26-80; cNPWT), 54 (18-80; gram+) and 53 (22-70; gram-) years while gender distribution was male to female: 67%:33% (cNPWT), 70%:30% (gram+), and 45%:55% (gram-).

Wound size was 183 cm² (cNPWT), 160 cm² (gram+), and 179 cm² (gram-) and wounds were located at the lower extremity (cNPWT: 53%/n = 8; gram+: 60%/n = 6; gram-: 67%/n = 6), the trunk (cNPWT: 40%/n = 6; gram+: 40%/n = 4; gram-: 22%/n = 2) and the upper extremity (cNPWT: 7%/n = 1; gram+: 0%/n = 0, gram-: 11%/n = 1).

All details regarding patient demographics are summarised in Tables 2 and 3. Example cases of traumatic, surgical, and chronic wounds are described in Figures 1-3.

3.2 | Treatment schedule

The mean duration of NPWTi-d treatment was 13.2 (6-32) (TW = 12.64; SW = 13.5; CW = 11.76; cNPWT = 13; gram+ = 12.3; gram- = 13.1) days (Tables 4 and 5). On average, 2 (TW = 2; SW = 2.1; CW = 1.9; cNPWT = 2.1; gram+ = 2; gram- = 2) dressing changes were performed, during an average hospital stay of 52.6 days (18-89) (TW = 52; SW = 53; CW = 47.5; cNPWT = 54; gram+ = 51.4; gram- = 53.2). A system change from conventional NPWT to NPWTi-d was performed in 50% of all cases (n = 15). Patients in subgroup cNPWT received conventional NPWT prior to NPWTi-d on average for 11 days. In 77% (n = 23) of all cases (TW 92%/n = 11; SW 50%/n = 5; CW 87.5%/n = 7; cNPWT 73%/n = 11; gram+ 80%/n = 8; gram- 77%/n = 7), granulation tissue was considered significantly improved by NPWTi-d application at the end of therapy.

Final defect reconstruction was carried out most frequently by split thickness skin grafts (AW 30%/n = 9; TW

TABLE 2 Demographics of patients and attributed wound types

Groups	All wounds (AW)	Traumatic (TW)	Surgical (SW)	Chronic (CW)
No. of patients	100% (30)	40% (12)	33% (10)	27% (8)
Age (mean; range)	55 (18-80) years	53 (29-70) years	54 (26-80) years	51 (18-65) years
Gender (male:female)	70%:30% (n = 21:9)	83%:17% (n = 10:2)	60%:40% (n = 6:4)	62.5%:37.5% (n = 5:3)
Wound location (UE:LE:Trunk)	7%:56%:37% (n = 2:17:11)	8%:92%:0% (n = 1:11:0)	10%:40%:50% (n = 1:4:5)	0%:25%:75% (n = 0:2:6)
Wound size (mean, range)	179 cm ² (6-1600)	134cm ² (515-1600)	179 cm ² (6-1470)	148 cm ² (9-375)
Tobacco abuse (y:n)	23%:77% (n = 7:23)	17%:83% (n = 2:10)	30%:70% (n = 3:7)	25%:75% (n = 2:6)
Relevant secondary Disease (CV:DM:VI:AD)	53%:23%:33%:27% (n = 16:7:10:8)	42%:17%:17%:8% (n = 5:2:2:1)	60%:10%:30%:30% (n = 6:1:3:3)	62.5%:50%:62.5%:50% (n = 5:4:5:4)

Note: Patient data for all wounds and separate subgroups.

Abbreviations: AD, adipositas; CV, cardiovascular disease; DM, diabetes mellitus; LE, lower extremity; n, no; UE, upper extremity; VI, venous insufficiency; y, yes.

Groups	cNPWT	Gram+	Gram–
No. of patients	50% (15)	33% (n = 10)	30% (n = 9)
Age (mean; range)	50 (26-80) years	54 (18-80)	53 (22-70)
Gender (male:female)	67%:33% (n = 10:5)	70%:30% (n = 7:3)	45%:55% (n = 4:5)
Wound location (UE:LE:Trunk)	7%:53%:40% (n = 1:8:6)	0%:60%:40% (n = 0:6:4)	11%:67%:22% (n = 1:6:2)
Wound size (mean, range)	183 cm ² (11-1600)	160 cm ² (6-1470)	179 cm ² (15-1600)
Tobacco abuse (y:n)	33%:67% (n = 5:10)	40%:60% (n = 4:6)	67%:33% (n = 6:3)
Relevant secondary disease (CV:DM:VI:AD)	33%:20%:13%:20% (n = 5:3:2:3)	50%:30%:40%: 30% (n = 5:3:4:3)	45%:45%:22%:33% (n = 4:4:2:3)

TABLE 3 Demographics for subgroups cNPWT, gram+ and gram–

Note: Patient data for subgroups cNPWT, gram+ and gram–.

Abbreviations: AD, adipositas; CV, cardiovascular disease; DM, diabetes mellitus; LE, lower extremity; n, no; UE, upper extremity; VI, venous insufficiency; y, yes.

42%/n = 5; SW 30%/n = 3; CW 12.5%/n = 1; cNPWT 13%/n = 2; gram+ 40%/n = 4; gram– 33%/n = 3), or by free microsurgical tissue transfer (AW 30%/n = 9; TW 33%/n = 4; SW 30%/n = 3; CW 25%/n = 2; cNPWT 53%/n = 8; gram+ 20%/n = 2; gram– 33%/n = 3). Other definitive wound closures were secondary suture in 17% (n = 5) (TW 17%/n = 2; SW 20%/n = 2; CW 12.5%/n = 1; cNPWT 7%/n = 1; gram+20%/n = 2; gram– 11%/n = 1) or local flap surgery (AW 13%/n = 4; TW 0%/n = 0; SW 10%/n = 1; CW 37.5%/n = 3; cNPWT 13%/n = 2; gram+20%/n = 2; gram– 11%/n = 1). Out of 30 enrolled patients, the reconstructive goal was achieved in 90% (n = 27). For the remaining 10% of patients (n = 3), reconstructive aims failed to be achieved due to inoperability of patients. These 3 patients (TW = 1; SW = 1; CW = 1) underwent outpatient wound treatment without primary closure. No procedure-specific complications due to NPWTi-d were detected.

3.3 | Microbiological evaluation

Before the initiation of NPWTi-d, only one type of bacteria was detected in 10 patients, whereas the wounds of the remaining 20 patients were colonised with more than 1 type of bacteria. Most commonly detected bacteria strains were *Staphylococcus aureus* in 11 and *Enterococcus faecalis* in 8 patients. Gram staining ratio was fairly even with gram-positive germs making up 60% and gram-negative germs 40% of all detected germs. Eleven patients had wounds with both, gram-positive and negative germs. We did not detect a shift towards different types

of bacteria during NPWTi-d treatment. Multiresistant bacteria, namely MRSA and 3MRGN, were detected in 5 patients.

For the total study population, microbiological analysis of tissue samples taken before and after NPWTi-d showed a statistically significant reduction of NDB from 2.38 to 1.16 ($P < .05$). This was accompanied by a statistically significant reduction of BC from 3.9 before NPWTi-d to 1.3 afterwards ($P < .05$).

For subgroups, similar results were revealed. In traumatic wounds (TW), NPWTi-d was as effective in significantly reducing both NDB (2.18-0.77; $P < .05$) and BC (2.6-0.9; $P < .05$). Similar results have been shown for chronic wounds (CW), in which NPWTi-d significantly decreased the bacterial load with a reduction of NDB from 2.2 to 1.17 and BC from 3.5 to 1.7 (both $P < .05$). For surgical wounds (SW), NPWTi-d significantly decreased NAB from 2.24 to 1.15 ($P < .05$), while the differences in BC yielded no statistically significant results with a reduction from 4.1 to 2.2 ($P > .05$). Interestingly, in one case of postoperative wounds, an increase of NDB was monitored during NPWTi-d treatment. For patients pretreated with conventional NPWT (cNPWT), initial NDB and BC after conventional NPWT and before NPWTi-d application did not differ significantly from patients who did not receive NPWT prior to NPWTi-d. For the cNPWT subgroup, NDB was significantly decreased from 2.7 to 1.07 ($P < .05$) through NPWTi-d treatment. Additionally, BC was significantly reduced from 3.4 to 2.2 ($P < .05$).

Analysis of germ types showed a NDB of 2.1 before and 1.1 after NPWTi-d in patient with isolated gram-

positive wound germs (gram+; $P < .05$). In this group, BC was reduced from 2.9 to 1.4 ($P < .05$). For gram-negative germs (gram-), NDB was reduced from 2.5 to 1.3 ($P < .05$) and BC was reduced from 3.2 to 2 ($P < .05$) through NPWTi-d.

Decontaminated wound conditions in prior colonised wounds could be achieved in 23% ($n = 7$) of cases (TW = 33%/ $n = 4$; SW 20%/ $n = 2$; CW 12.5%/ $n = 1$). For other subgroups, decontaminated wounds were achieved in 20% ($n = 3$; cNPWT), 30% ($n = 3$; gram+), and 22% ($n = 2$; gram-). Results of microbiological evaluation are depicted in Tables 4 and 5 as well as Figure 4.

4 | DISCUSSION

Complex wounds of traumatic, surgical, or chronic origin require decisive and effective treatment regimes to overcome the bacterial burden, re-establish wound bed integrity and enable wound closure or reconstruction.

Clinical and animal studies both have reported that NPWTi-d using saline or topical anti-infective solutions may support the management of the wound's bioburden and wounds with infection.^{3,9,10} The reduction of the bacterial burden in conjunction with wound bed stabilisation has been shown to be an important step towards successful defect coverage by reconstructive surgery.^{10,11}

In the presented study, we aimed to evaluate the impact of NPWTi-d with saline installation on decontamination by reducing both, the bacterial load and spectrum of different complex soft tissue wounds. In a few cases, an additional NPWTi-d cycle was applied when the results were promising but wounds were not yet deemed ready for final closure. One less cycle was applied when the wounds appeared ready for closure. All included wounds displayed colonisation with a minimum of one bacterial species. Furthermore, subgroup analysis showed that NPWTi-d could promote wound bed stabilisation for all wound types separately. Regarding the semi-quantitative measurements of bacterial load, NPWTi-d was successful in significantly reducing the bacterial count. Yet, when we addressed different wound types in our



FIGURE 1 Case of a patient treated with NPWTi-d with a traumatic wound. A 56-year-old patient suffered from a shotgun blast injury to his right foot (A, B). After initial surgical debridement and conventional NPWT, a plantar and dorsal soft tissue defect with exposed tendons and bones resulted (C, D; *). Microbiological analysis then revealed colonisation with 3 different bacterial species, and NPWTi-d was applied for early therapy of bacterial colonisation (E, F). Ten days/2 cycles later, wounds were successfully decontaminated and ready for final closure. Closure was performed by microsurgical free flap using a compound flap (anterolateral thigh + vastus) conjugated via the descending branch for dorsal and plantar resurfacing and reconstruction (G, H; *)



FIGURE 2 Case of a patient treated with NPWTi-d with a surgical wound. A 26-year-old female spina bifida patient received dorsal instrumentation for spine stabilisation. After a complex and protracted course, a lumbar wound with partly exposed hardware resulted (A, B). Local rotation flaps were performed to decrease defect size, however, wound dehiscence (*) remained (C). In the absence of surgical alternatives, skin grafting was scheduled, but wound bed situation was without sufficient granulation tissue. NPWTi-d was applied on day 24 (D). Ten days later, wound integrity was restored, and bacterial load decreased, thus skin grafting (E, *) and secondary suture (F, *) were performed. Another 2 weeks later (G) on day 60 of treatment, the patient left the clinic to a neurologically orthopaedic rehabilitation unit to be mobilised within her possibilities

subgroup analysis, no significant reduction of the postoperative bacterial count was achieved in surgical wounds. Surgical wounds contained the most bacteria, which might be due to the nature of postoperative wounds: Patients developing postoperative wounds usually have a high-risk profile with several comorbidities. This results in reduced healing conditions and therefore

compromised wound beds. These wound conditions could negatively influence the effects of NPWTi-d on bacterial decontamination; however, further studies are necessary to fully investigate this effect and the special nature of surgical wounds.

Despite the proposed mechanisms of antiseptic solutions, instillation of plain saline showed great beneficial

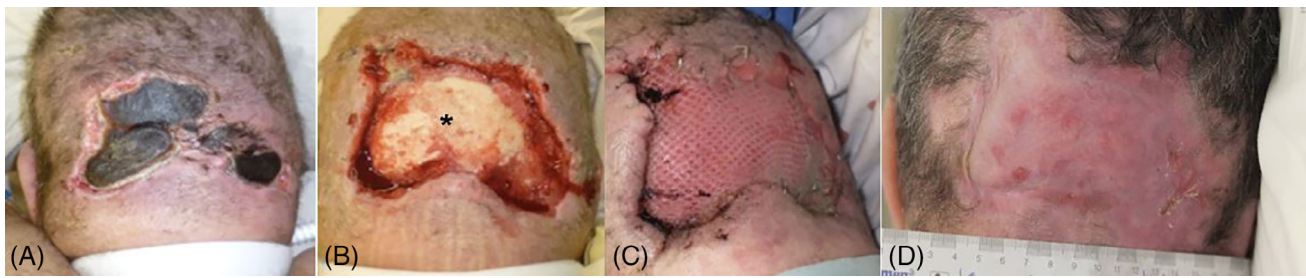


FIGURE 3 Case of a patient treated with NPWTi-d with a chronic wound. He suffered from a Ddeep infected necrosis at the back of his head/neck region due to a “Stiff-Neck”—related pressure ulcer (A). After decontamination without reconstructive alternatives for the critically ill patient beyond microsurgery (B; * indicates debrided tabula externa), NPWTi-d was applied to improve the wound bed integrity. After 2 cycles of NPWTi-d, split-thickness skin grafts were transplanted and fixed with conventional NPWT (C). The regime resulted in successful take of split-thickness skin graft and discharge on day 56 in hospital with closed wounds (D)

TABLE 4 Results for all wounds and different wound types before and after NPWTi-d treatment

Groups	All wounds (AW)	Traumatic (TW)	Surgical (SW)	Chronic (CW)
NDB before	2.38	2.18	2.24	2.2
NDB after	1.16	0.77	1.15	1.17
BC before	3.9	2.6	4.1	3.5
BC after	1.3	0.9	2.2	1.7
Decontaminated wounds in n cases after NPWTi-d	23% (n = 7)	33% (n = 4)	20% (n = 2)	12.5% (n = 1)
NPWTi-d treatment, days (mean)	13.2	12.64	13.5	11.76
NPWTi-d dressing changes (mean)	2	2	2.1	1.9
Total length of Hospitalisation, days (mean)	52.6	52	53	47.5

Note: Bold letters indicated statistically significant results.

Abbreviations: BC, bacterial count before and after NPWTi-d treatment; NDB, number of different bacteria.

TABLE 5 Results for subgroups cNPWT, gram+ and gram–

Groups	cNPWT	gram+	gram–
NDB before	2.7	2.1	2.5
NDB after	1.07	1.1	1.3
BC before	3.4	2.9	3.2
BC after	2.2	1.4	2
Decontaminated wounds in n cases after NPWTi-d	20% (n = 3)	30% (n = 3)	22% (n = 2)
NPWTi-d treatment, days (mean)	13	12.3	13.1
NPWTi-d dressing changes (mean)	2.1	2	2
Total length of hospitalisation, days (mean)	54	51.4	53.2

Note: Bold letters indicated statistically significant results.

Abbreviations: BC, bacterial count before and after NPWTi-d treatment; NDB, number of different bacteria.

results in the published data.¹²⁻¹⁵ In a large prospective trial by Ludolph et al, NPWTi-d with instillation of 0.4 mg/L polyhexanide solution was capable of reducing the bacterial load of several different wound types.¹⁶ In our study, instillation and dwell time with saline for 10 minutes was sufficient to achieve comparable results, more specifically addressing the different wound types in subgroups. The results of our study suggest that active irrigation with dwell

time is the key step to treat bacterial wound colonisation rather than the use of an active instillation solution. These findings are supported by a study by Kim et al, comparing saline with polyhexanide instillation in 100 patients favouring saline solution for the analysed cohort.¹¹ In our opinion, NPWTi-d is more than a temporary wound cover. It acts as a component of the reconstructive ladder and an active tool for wound therapy.

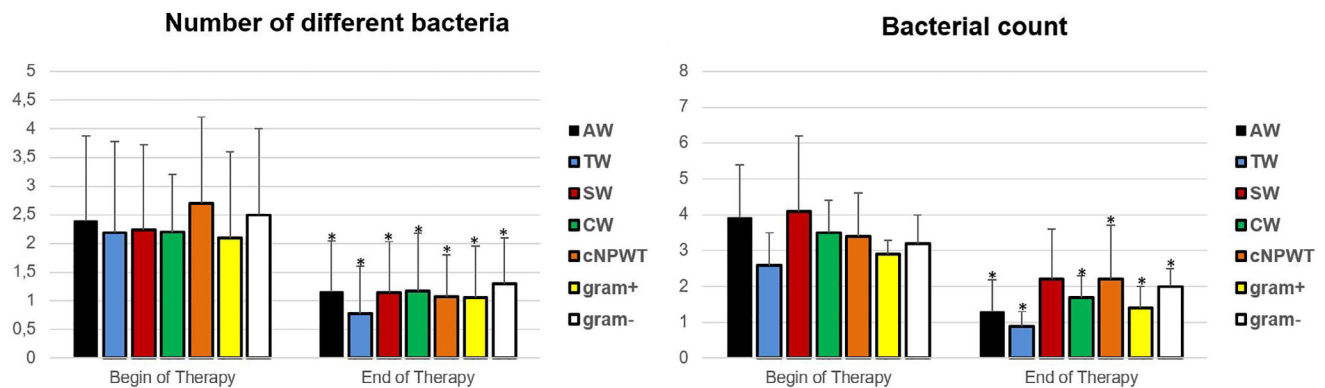


FIGURE 4 Graphical display of microbiological dynamics and the effect of NPWTi-d (number of different germs and bacterial counts) in all wounds, wound subtypes, and different microbiological characteristics. Mean values and standard deviation of number of different bacteria (left) and bacterial count (right) for all wounds (AW) and the subgroups traumatic (TW), surgical (SW), chronic (CW) wounds, cNPWT (with previous conventional NPWT treatment), gram+ (gram-positive germs), and gram- (gram-negative germs). Stars indicate significant differences compared with “Begin of Therapy”

The present study has some limitations, which need to be discussed: Indisputable, this study may reflect our everyday inhomogeneous patient population and wound types, which underlines the difficulties to standardise wounds for comparative studies. To deal with this heterogeneity, we defined inclusion and exclusion criteria and performed a subtype analysis for different wound type origins (traumatic, postsurgical, chronic). Another limitation of the present study is the lack of a comparative group treated with the standard of care (SOC), surgical debridement followed by conservative dressings with or without antiseptic solutions and/ or conventional NPWT. It is hardly possible to standardise wound types for a matched-pair or comparative study, and SOC treatment would raise to many. As a historical control group would not be expedient and fulfil the expectations of a matched-pair or comparative design for the readership, we had to focus on the effect of NPWTi-d alone. Nevertheless, we used internal controls for our statistical analysis, comparing microbiological results of tissue biopsies at different time points of NPWTi-d treatment (before and after). Furthermore, evaluation of granulation tissue formation at each dressing change, as performed by experienced surgeons, is a rather subjective method, not quantifiable for statistical analysis.

In our center, NPWTi-d has found its place as a therapeutic tool in the management of complex soft tissue wounds to optimise the outcomes. It is crucial to define a therapeutic aim, which should be achieved in a clearly defined maximum time of therapy. Re-evaluation is part of modern treatment concepts, also required for successful implementation of NPWTi-d. In order to improve the level of evidence on NPWTi-d, comparative, randomised trials are necessary with standardised regimes and optimally matched wound types.

5 | CONCLUSION

In the present study, we were able to demonstrate that NPWTi-d successfully led to the reduction of the bacterial load and spectrum in complex wounds. NPWTi-d shows promising results especially for traumatic and chronic wounds and can serve as a helpful tool in the plastic and reconstructive armamentarium.

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CONFLICT OF INTEREST

This is an investigator-initiated study. The V. A. C. VerFlo dressings for NPWTi-d were provided free of charge.

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