Negative pressure wound therapy, silver coated foam dressing and conventional bandages in open wound treatment in dogs

A retrospective comparison of 50 paired cases

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Keywords
Negative pressure wound therapy, foam dressing, bacterial wound contamination, open wound management, wound bed preparation

Summary
Objectives: To evaluate negative pressure wound therapy (NPWT) for treatment of complicated wounds in dogs.

Study type: Retrospective multicentre study.

Materials and methods: Dogs (n = 50) undergoing open wound treatment were classified according to treatment method used: bandage (Group A, n = 7), NPWT (Group B, n = 18), and foam dressing (Group C, n = 25). Pairs of patients matched based on wound conformation, localization, and underlying cause were compared between Group A and C (n = 7 pairs) and between groups B and C (n = 18 pairs) in terms of duration of previous treatment, time to closure, and complications.

Results: Signalment, antibiotic medications, antiseptic treatment, and bacterial status of wounds were comparable between groups. The duration of previous treatment was significantly higher in patients assigned to Group B (p = 0.04) compared to Group C, while no significant difference was found between groups A and B. Total time to wound closure was significantly shorter in Group C compared to Group A (p = 0.02) and in Group B compared to Group C (p = 0.003). Wounds treated with NPWT suffered significantly less complications (p = 0.008) and were significantly less septic during treatment (p = 0.016) than wounds treated with a foam dressing.

Conclusion: This study shows that time to healing was halved in NPWT treated patients compared to foam dressing treated patients, which in turn healed faster than patients treated with conventional bandage, underlining the value of NPWT therapy for the treatment of complicated wounds.

Introduction
Negative pressure wound therapy (NPWT) allows for the enhancement of wound healing by the application of a homogeneous vacuum to the wound via a sponge (1). Although the main effects by which NPWT improves wound healing have been elucidated, the full extent of NPWT is yet to be discovered (2–10). Over the past ten years indications including urine-induced necrosis, burn injuries, augmentation of shear injuries, augmentation of local flaps, and septic peritonitis have been described in the veterinary literature (11–20). Two experimental trials in dogs have been conducted to assess the effect of NPWT on open wound healing and skin graft augmentation and recently, a clinical case series of 45 veterinary patients undergoing NPWT treatment for various traumatic wounds was published (21-23). More reports have been published on NPWT than on any other wound dressing in small animals, but there is a paucity of clinical trials that objectively compare NPWT to controls. The aim of this study was to evaluate the outcome of NPWT when used for open wound therapy in dogs, and to compare it to a standard treatment protocol.

Materials and methods
The medical records of two clinics (Clinic of Small Animal Surgery and Reproduction, Ludwig-Maximilians University, Munich, Germany) were reviewed retrospectively to identify dogs with open wounds treated using NPWT. Patients were matched based on wound conformation, localization, and underlying cause and treated using NPWT, conventional bandage, or foam dressing. The duration of previous treatment, time to closure, and complications were recorded and compared between groups.
production, Ludwig-Maximilians-University in Munich, Germany and Small Animal Clinic of the University of Veterinary Medicine, Foundation in Hanover, Germany) in the period between January 2011 and October 2013 were searched for patients that underwent open wound therapy. Records were included if dressing changes, time to closure, and a minimum follow-up of 14 days after closure were documented. Based on the type of treatment, patients were assigned to three groups: Group A (n = 7) conventional bandage with non-adherent gauze, Group B (n = 18) NPWT, and Group C (n = 36) foam dressing.

**Treatment protocols**

In patients assigned to Group A, non-adhesive gauze\(^a\) was applied to the wound which had been debrided and cleaned at the first presentation. The gauze was secured by a protective bandage and changed daily until the infection was under control. Bandage changes were then performed every two to three days. In patients with major injuries, such as those involving the thoracic wall or neck, changes were performed until the infection was under control while the patient was under general anaesthesia to allow repeated wound debridement and advancement of the wound margins.

Group B patients were treated by application of a NPWT dressing\(^b\) after initial debridement (Figure 1). Dressing changes were performed while the patient was under general anaesthesia every two to three days and a continuous vacuum between –125 and –100 mm/Hg was applied. Negative pressure wound therapy was performed at a pressure of –125 mm/Hg, continuous mode, at the Clinic for Small Animal Surgery and Reproduction of the Ludwig-Maximilian-University in Munich. At the Small Animal Clinic of the University of Veterinary Medicine in Hanover, this pressure (–125 mm/Hg) was only used initially in most patients as this high negative pressure often resulted in leakage. The vacuum was thus usually reduced to –100 mm/Hg after the initial phase of treatment. At this rate no problems with leakage occurred. The NPWT treatment was discontinued once a healthy granulation bed had formed. Thereafter, therapy was continued using a triple layered silver-coated foam dressing\(^c\) until the wound was completely healed.

In Group C, wound treatment was identical to Group B except that a foil-coated highly absorbent foam\(^d\) was applied initially as long as massive wound exudation occurred instead of an NPWT device (this had been the treatment protocol for open, exudating wounds prior to introduction of the NPWT system). Once the amount of exudation decreased, the dressing was changed to a silver-coated foam dressing\(^c\) (Figure 2). Foam dressings were sutured directly to the wounds to prevent dislodgement of the dressing, and dressing changes were performed while the patient was under general anaesthesia. Dressing changes were performed every two- to three days as in the NPWT group. Surgical advancement of the wound edges was performed during dressing changes in all patients of Groups B and C. The wound edges were therefore undermined by ap-

\(^{a}\) Adaptic: Systagenix Wound Management GmbH, Gargrave, UK
\(^{b}\) V.A.C. GranuFoam\textsuperscript{TM}, TracPad\textsuperscript{TM}: V.A.C. Freedom: KCI, Wiesbaden, Germany
\(^{c}\) Acticoat Moisture Control: Smith&Nephew GmbH, Hamburg, Germany
\(^{d}\) ALLEYVIN Cavity: Smith&Nephew GmbH, Hamburg, Germany

**Figure 1** Appearance of a representative wound for negative pressure wound therapy (NPWT) treatment (Group B). A) Initial status of the infected wound, B) appearance after debridement, C) after application of NPWT dressing, and D) after a week of therapy.
proximately 1–2 cm and the skin was advanced toward the centre of the defect and secured there using walking sutures. This way, the wound size could be reduced while keeping the wound open and allowing maximal wound drainage since most of the cases were severely infected and had already failed previous attempts at closure. Otherwise the wounds were allowed to heal by second intention healing without further reconstructive procedures.

**Study design**

For each dog, signalment data, including breed, age, sex and weight, were recorded as well as known co-morbidities. In addition, initial antibiotic drug treatment used, as well as changes in the antibiotic therapy due to results of the resistance testing of the local bacterial load in the wounds, and antiseptic treatment were recorded.

Wounds were further characterized using the following parameters: duration of previous treatment, cause of wound development, wound type (acute or chronic), location of the wound, presence of infection (swelling, pain, discharge, presence of necrosis), and wound class (using a rule of nine classification: 1 = small defect, no wound pockets; 2 = medium sized defect (<15% body surface area (BSA)), no wound pockets; 3 = medium sized defect (<15% BSA), with pockets; 4 = large defect (>15% BSA), no wound pockets; 5 = large defect (>15% BSA) with pockets; 6 = defect with associated metal implant) at the initiation of the documented treatment.

Based on this information, pairs of patients were assigned to each other in order to compensate for bias caused by the impact of the wounds on healing.

If available, the microbial status of the wound at initiation of therapy and during treatment (during NPWT treatment in Group B, during foam treatment in Group C), including the number of isolated bacterial species, and resistance profiles of isolated bacteria were recorded and compared between groups. Since bacterial culture results were not available for most patients in Group A, evaluation and comparison of these parameters were restricted to matched pairs of Groups B and C.

Outcome measures were defined as total time to closure, complications observed during therapy, and observed compli-

![Figure 2](image-url) Typical appearance of a wound representative for foam dressing treatment. A) Initial status of the infected wound, B) appearance after debridement, C) after application of the foam dressing, and D) after a week of therapy.
cations after closure in terms of ongoing wound healing deficiencies such as dehiscence, seroma formation and repeated infection.

Statistical analysis

Statistical analysis was performed using commercial software. Categorical variables were expressed as frequency and continuous data were expressed as median and range. An unpaired t-test was used to assess differences between groups for continuous, normally distributed data, and a Wilcoxon rank-sum test was used for non-normally distributed parameters. A Fischer’s exact test was used to compare categorical variables. Significance was set at p < 0.05.

Results

During the study period, a total of 61 dogs underwent open wound treatment. Of these, seven dogs were treated using conventional bandages (Group A), 18 dogs were treated using NPWT (Group B), and 36 dogs were treated using foam dressing only (Group C). We were able to match seven comparable pairs of patients in Groups A and C and 18 pairs in Groups B and C. Thus a total of 50 patients were included in pairwise comparisons. Matching was not possible between patients in Groups A and B since the wound parameters between these groups were too heterogeneous to allow comparison.

Signalement

Group A and C comparison

Mean age of patients in Group A was 5.3 years (range: 1–9 years), and mean body weight was 15.8 kg (range: 2.5–30 kg). The corresponding partners in Group C had a mean age of 5.7 years (range: 1–10 years), and a mean body weight of 14 kg (range: 2.9–28 kg). Further details are listed in Appendix Table 1 (available online at www.vcot-online.com).

Groups B and C comparison

In the matched pairs of Groups B and C, mean age in Group B was 4.7 years (range: 1–11 years) with a mean body weight of 27.1 kg (range: 6.5–63 kg), while mean age of patients of Group C was 6.2 years (range: 1–13 years) with a mean body weight of 15.9 kg (range: 2.9 – 32.4 kg). Further details can be found in Appendix Table 2 (available online at www.vcot-online.com).

Table 1  Characterization of previous treatment of patients before inclusion in the study.

<table>
<thead>
<tr>
<th>Previous Treatment*</th>
<th>Groups A and C comparison</th>
<th>Groups B and C comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A (n = 7)</td>
<td>Group C (n = 7)</td>
</tr>
<tr>
<td>Antibiotic treatment*</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Surgical debridement with drains*</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Open wound treatment*</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Duration of previous treatment</td>
<td>10.6 days (range: 4–309)</td>
<td>9 days (range: 6–16)</td>
</tr>
</tbody>
</table>

*Values shown are number of patients.

Groups B and C comparison

Five patients in Group A and four in Group C had previous wound treatment before presentation including surgical treatment, antibiotic drug treatment with different substances, or both. Of these, four (Group A) and one (Group C) patients respectively had undergone previous surgical treatment. Further details are given in Table 1. Mean treatment duration was 10.6 days in Group A (range: 4–30 days) and nine days in Group C (range: 6–16 days). No significant differences were detected.

Antibiotic Medication

The main antibiotic drug used for treatment was amoxicillin with clavulanic acid. Additional antibiotic medications used as initial treatment included marbofloxacin, pradofloxacin, enrofloxacin, metronidazole, doxycycline, cefazolin, cefiotur, trimethoprim sulphonamide and gentamycin. There was no significant difference between treatment regime or substance between groups.

Groups A and C comparison

Six patients in Group A and seven patients in Group C received antibiotic treatment at initial debridement. Six patients in Group A and five patients in Group C received treatment using a single antibiotic drug while two patients in Group C received multiple antibiotic drugs. The antibiotic drug was chosen based on susceptibility testing in three patients in Group A and in five patients in group C. The chosen drug was adjusted in three patients during therapy in Group A and in four patients in Group C. Further details are given in Table 2.

No significant differences between groups in terms of changes of treatment or the chosen antibiotic medication were found.

Table 2.

<table>
<thead>
<tr>
<th>Antibiotic Medication</th>
<th>Groups A (n = 7)</th>
<th>Group C (n = 7)</th>
<th>Group B (n = 18)</th>
<th>Group C (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marbofloxacin</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Pradofloxacin</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Enrofloxacin</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Metronidazole</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Doxycycline</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cefazolin</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cefiotur</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Trimethoprim sulphonamide</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Gentamycin</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

All patients in Groups B (n = 18) and C (n = 18) received antibiotic treatment at initial debridement. In both groups, 13 patients each were treated using a single antibiotic drug.
drug while five patients in Group B and five patients in Group C received multiple antibiotic drugs. The antibiotic drug was chosen based on susceptibility testing in all patients in both groups. The chosen drug was adjusted in seven patients during therapy in Group C and in five patients in Group C. Further details are given in Table 2.

No significant differences between groups in terms of changes of treatment or chosen antibiotic medication were found.

### Antiseptic treatment
Polyhexanide 0.04% was used for local wound treatment in the majority of cases. Further details are given in Table 2.

### Bacterial culture
#### Groups A and C comparison
Bacterial culturing was not performed or was not available in most of the cases within Group A, thus statistical evaluation of this parameter could not be performed for this group.

#### Groups B and C comparison
Bacterial culture results at initial debridement were available for all pairs of Groups B and C. The mean number of bacterial species isolated at initial debridement was two in both groups (Group B range: 1–4; Group C range: 0–5). None of the patients in Group B and three of the patients in Group C were initially tested negative. Isolated bacteria species included: *Escherichia coli* (Group B, n = 4; Group C, n = 7), *Enterococcus spp.* (Group B, n = 5; Group C, n = 3), *Enterobacter spp.* (Group B, n = 1; Group C, n = 3), *Staphylococcus pseudintermedius* (Group B, n = 4; Group C, n = 5), *Pseudomonas aeruginosa* (Group B, n = 5; Group C, n = 3), *Streptococcus canis* (Group B and C, n = 1), *Acinetobacter baumannii* (Group B, n = 4; Group C, n = 1), *Actinomyces spp.* (Group B, n = 2), *Aeromonas spp.* (Group B, n = 1), *Hafnia* (Group B, n = 1), *Moraxella* (Group C, n = 1), *Bacteroides spp.* (Group C, n = 1), *Arthrobacter spp.* (Group C, n = 1), *Pasteurella multocida* (Group C, n = 4), *Coryneformes* (Group C, n = 1), *Prevotella spp.* (Group C, n = 1) and *Raoultella spp.* (Group C, n = 1). In twelve patients in Group B and nine patients in Group C, the identified isolates were resistant to more than three antibiotic classes.

Repeated bacterial culture results during therapy were available for 15 patients in Group B, and 10 patients in Group C. The mean number of isolated bacterial species during therapy was one in both groups (range: 0–4 in both groups). Isolated species included: *Enterococcus spp.* (Group B, n = 1; Group C, n = 2), *Escherichia coli* (Group B, n = 1; Group C, n = 3), *Enterobacter spp.* (Group B, n = 2), *Staphylococcus pseudintermedius* (Group C, n = 1), *Pseudomonas aeruginosa* (Group B, n = 7) [2 remaining colonization, 5 new colonizations]; Group C, n = 2) and *Aeromonas spp.* (Group B, n = 1) (Figure 3).

Compared to the bacterial infection status at the beginning of therapy, eight of the patients in Group B and five of the patients in Group C that had been tested positive in the beginning became negative over the course of the treatment. One patient (Group C) which had formerly tested negative was tested positive for *Enterococ-

### Table 2
Antibiotic and antiseptic treatment of the patients given in number of patients treated.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Groups A and C comparison</th>
<th>Groups B and C comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group A (n = 7)</td>
<td>Group C (n = 7)</td>
</tr>
<tr>
<td>Bacterial culture available</td>
<td>3 5</td>
<td>18 18</td>
</tr>
<tr>
<td>Antibiotic treatment during therapy</td>
<td>6 7</td>
<td>18 18</td>
</tr>
<tr>
<td>Monotherapy</td>
<td>6 5</td>
<td>13 13</td>
</tr>
<tr>
<td>- Amoxicillin with clavulanic acid</td>
<td>3 4</td>
<td>11 9</td>
</tr>
<tr>
<td>- Cefazolin</td>
<td>1 1</td>
<td>0 2</td>
</tr>
<tr>
<td>- Cefotiofur</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>- Doxycycline</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>- Marbofloxacine</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>- Pradofloxacine</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>- Trimetoprim sulfonamide</td>
<td>0 0</td>
<td>1 1</td>
</tr>
<tr>
<td>Multiple antibiotics</td>
<td>0 2</td>
<td>5 5</td>
</tr>
<tr>
<td>- Amoxicillin with clavulanic acid + metronidazole</td>
<td>0 0</td>
<td>2 4</td>
</tr>
<tr>
<td>- Amoxicillin with clavulanic acid + marbofloxacine</td>
<td>0 1</td>
<td>1 1</td>
</tr>
<tr>
<td>- Cefotiofur + metronidazole</td>
<td>0 1</td>
<td>1 1</td>
</tr>
<tr>
<td>- Cefotiofur + enrofloxacine</td>
<td>0 0</td>
<td>0 0</td>
</tr>
<tr>
<td>- Marbofloxacine + metronidazole</td>
<td>0 0</td>
<td>1 1</td>
</tr>
<tr>
<td>Based on susceptibility testing</td>
<td>3 5</td>
<td>18 18</td>
</tr>
<tr>
<td>Adjusted during treatment</td>
<td>3 4</td>
<td>7 5</td>
</tr>
<tr>
<td>- Marbofloxacine</td>
<td>2 2</td>
<td>5 2</td>
</tr>
<tr>
<td>- Pradofloxacine</td>
<td>0 0</td>
<td>1 0</td>
</tr>
<tr>
<td>- Enrofloxacine</td>
<td>1 0</td>
<td>0 0</td>
</tr>
<tr>
<td>- Doxycycline</td>
<td>0 2</td>
<td>1 3</td>
</tr>
<tr>
<td>Discontinued during treatment</td>
<td>2 0</td>
<td>2 0</td>
</tr>
<tr>
<td>Antiseptic treatment during therapy</td>
<td>7 7</td>
<td>18 18</td>
</tr>
<tr>
<td>- Polyhexanide</td>
<td>7 6</td>
<td>18 18</td>
</tr>
<tr>
<td>- Polyvidone iodine</td>
<td>0 1</td>
<td>1 0</td>
</tr>
<tr>
<td>- Acetic acid</td>
<td>0 0</td>
<td>0 0</td>
</tr>
</tbody>
</table>
Enterococcus spp. during treatment. In four patients in Group B and four patients in Group C, the resistance to antibiotic classes increased during treatment.

**Wound characteristics**

**Groups A and C comparison**

In matched pairs between Groups A and C, the majority of wounds were considered minor. All but one wound in Group A were considered acute and the majority were caused by infection, followed by trauma (▶Table 3). The location of wounds in these matched pairs included: neck (Group A and C: 1/7 each; limb (Group A: 3/7, Group C: 4/7); thoracic wall (Group A and C: 1/7 each), elbow (Group A: 1/7), toe (Group A: 1/7) and scrotum (Group C: 1/7) (▶Appendix Table 1 – available online at www.vcot-online.com). Regarding the clinical presentation on initial examination, five wounds in Group A and four wounds in Group C showed clinical signs of infection.

**Groups B and C comparison**

In matched pairs between Groups B and C, the majority of the wounds were considered major. Most wounds were considered acute, and the most frequent reason for wound development was infection, followed by trauma and other causes (▶Table 3). The location of wounds in these matched pairs included: neck (Group B: 6/18, Group C: 3/18), hip (Group B: 3/18), limb (Group B: 1/18, Group C: 4/18), stifle (Group B: 1/18), toe (Group B: 1/18), thoracic wall (Group B: 1/18, Group C: 3/18), dorsum (Group B: 1/18), head (Group C: 1/18), shoulder (Group B: 1/18, Group C: 3/18), abdominal wall (Group B: 3/18, Group C: 2/18) and scrotum (Group C: 1/18) (▶Appendix Table 2 - available online at www.vcot-online.com).

Regarding the clinical presentation on initial examination, 16 wounds in Group B and 17 wounds in Group C showed clinical signs of infection.

**Outcome**

**Groups A and C comparison**

Wound closure was achieved in six out of seven patients in Group A and all
groups were statistically significant. The mean total time to closure in Group C (14.4 days, range: 5–24 days) was significantly shorter (p = 0.02) for patients in treatment Group A (33.7 days, range: 16–55 days) compared to corresponding patients in Group C (14.4 days, range: 5–24 days).

Groups B and C comparison

When comparing NPWT and foam treated patients, we found that mean total time to closure was significantly shorter (p = 0.003) in patients from Group B (15.7 days, range: 6–34 days) when compared to corresponding patients from Group C (29.9 days, range: 5–75 days).

Discussion

Numerous publications have reported the beneficial effect of NPWT treatment on healing of complicated wounds in humans and animals (1–20). Unfortunately, objective data on the efficacy of NPWT compared to standard treatment protocols are sparse. The current study provides preliminary information on the effect of NPWT treatment for complicated wounds in patients.

Wounds can be very heterogeneous; the age of the patient, as well as the size, age, location of the wound, and presence of infection are parameters that influence healing to a great degree (24). Therefore, comparison of the groups without regard to those parameters would have biased the evaluation. In order to compensate for this potential bias, matched pairs of patients were assigned for evaluation of outcome parameters. As already mentioned, patients in Group A frequently had minor wounds, while patients were treated with NPWT (Group B) if they had severe, hard-to-treat wounds. This fact is underlined by the significantly longer duration of previous therapy in this group compared to the others. Because of that, it was not possible to form comparable pairs between Groups A and B. Thus, for comparison of outcome variables,
only patients of Groups A and C, and Groups B and C were compared. There are numerous wound dressings available. Wet-to-dry and dry-to-dry bandages have been frequently used in open wound treatment previously (24). These bandages lead to mechanical debridement of the wound surface during dressing changes even if a non-adherent gauze is interposed. Moreover, the wound exudate is absorbed or evaporates through the dressing, leading to the loss of growth factors and cells during therapy (24). Such dressings are therefore no longer considered to meet the standard of care in human medicine and their use should be limited in veterinary patients since more effective options are available (25). Moist wound healing supports the needs of the wound with regard to temperature, moisture, osmolarity and gas exchange (25, 26). In the past, the standard dressing for moist wound healing in both institutions taking part in this study was foil coated polyurethane foam dressing for highly exudative wounds, and triple layered silver coated foam dressing in wounds in which exudation was at, or decreased to normal levels. It has been documented that the use of silver coated foam prevented maceration of the peri-wound skin area, reduced clinical signs of infection and wound area, and promoted healing (27). Silver ions have been shown to have antimicrobial efficacy against bacteria that were resistant to various antibiotics in vitro, and various silver dressings have been shown to reduce bacterial load in infected wounds in vivo, although these findings are still under debate (18, 28–30).

Wackenfors stated in 2004 that “the physiological and molecular biological mechanisms by which V.A.C (vacuum-assisted closure) therapy accelerates wound healing are to a large extend unknown”, but the following effects have been shown: NPWT results in a uniform reduction of interstitial oedema due to active fluid drainage and thus to a reduction of interstitial pressure and an increase of blood flow within the tissue under the sponge (3, 8, 9). This increase of up to 50% in perfusion levels can be achieved within 1.5 cm under the sponge, and the effect of the vacuum extended as far as 3 cm under the sponge (8). Investigations of the effect of vacuum on tissue perfusion found that a negative pressure of -125 mm/Hg was most effective at promoting perfusion, while higher values impaired blood flow (3). Ever since, this value has been standard in most NPWT-use guidelines (3). Negative pressure wound therapy is also known to cause a significant increase in the amount of granulation tissue formation when compared to control groups using standard open wound management (3, 21, 31, 32). This effect is thought to be due to the enhancement of fibroblast proliferation due to mechanical cell deformation (10, 32). Another study documented fast and smooth granulation of wounds under NPWT therapy in patients (21). In contrast to granulation, epithelisation did not occur under the sponge during therapy (21). However, according to that study, re-epithelisation after discontinuation of treatment was rapid (21). Unfortunately, the authors did not state whether the total time to full closure was reduced in NPWT-treated patients when compared to the controls.

The current standard treatment pressure for NPWT is -125 mm/Hg (3). Leakage that occurred using this pressure in the Small Animal Clinic of the University of Veterinary Medicine, Hannover might indicate a difference in dressing application technique. We cannot say whether this difference influenced treatment efficiency since no data are available regarding healing rates under different negative pressures in small animals.

In the beginning, the achievement of an airtight seal can be challenging in mobile patients and in difficult wound locations. However, with practice, the application of airtight dressings becomes easier.

A postulated benefit of NPWT is enhanced bacterial clearance. This effect has been controversially discussed in the literature. Some authors showed that NPWT increased bacterial clearance due to modulation of the inflammatory reaction and increased blood flow while others found no beneficial effect when compared to control groups, different effects for different bacterial species, or even higher bacterial loads after NPWT (3, 21, 33–35). Wounds may become contaminated with varying numbers of bacteria originating from the environment or the patient (36). The extent to which these micro-organisms affect healing depends on the host immune status as well as the number and virulence of the bacteria. Often wounds are ’colonized’ by bacteria, however, in contrast to wounds that are considered ‘infected’, the resident bacteria in ‘colonized’ wounds do not harm the patient or influence healing (27, 36). Bacterial species that are likely to be present in open wounds in patients during treatment include Staphylococcus aureus, Staphylococcus epidermidis, Streptococcus spp., Escherichia coli and Proteus spp. (36). Bacterial status was evaluated for wounds in Groups B and C, and a variety of different species was found at the beginning of therapy in both groups. However, the total numbers of cultures and individual isolates was relatively small and did not permit statistical evaluation. The isolated species were mainly faecal bacteria. Staphylococcus pseudintermedius was only detected in a few cases, while Pseudomonas were frequently cultured, especially in NPWT patients. Despite statistical evaluation not being possible due to the relative low number of culture results, this result was surprising. The mean percentage of different bacterial species isolated from all patients in the Clinic for Small Animal Surgery and Reproduction of the Ludwig-Maximilians University, Munich, (determined between 2009–2011) was available (Figure 3). In this dataset, S. pseudintermedius represented 21.9% of all isolates detected in the clinic over three years, while Pseudomonas aeruginosa represented only 4.8% of the total isolated bacteria (n = 1036). Thus, compared with this ’average’ distribution of bacterial species isolated in the clinic, it seems that P. aeruginosa was overrepresented in the NPWT-treated patients.

Progression of infection and sepsis was more effectively controlled in the NPWT group than in foam-treated patients. This finding supports the claim of NPWT being an effective mechanism of local infection control (3, 5, 6).

Several trials have demonstrated that NPWT treatment accelerates wound healing compared with conventional dressings in human medicine, but corresponding studies have not been reported for small
animal patients (36, 37). The findings of our study showed that time to healing was halved in NPWT-treated animals compared to foam dressing-treated patients, which in turn healed faster than patients treated with conventional bandage.

**Conflict of interest**
None declared.

**References**