

# Negative-Pressure Wound Therapy with Instillation: International Consensus Guidelines

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**Background:** Negative-pressure wound therapy with instillation is increasingly utilized as an adjunct therapy for a wide variety of wounds. Despite its growing popularity, there is a paucity of evidence and lack of guidance to provide effective use of this therapy.

**Methods:** A panel of experts was convened to provide guidance regarding the appropriate use of negative-pressure wound therapy with instillation. A face-to-face meeting was held where the available evidence was discussed and individual clinical experience with this therapy was shared. Follow-up communication among the panelists continued until consensus was achieved. The final consensus recommendations were derived through more than 80 percent agreement among the panelists.

**Results:** Nine consensus statements were generated that address the appropriate use of negative-pressure wound therapy with instillation. The question of clinical effectiveness of this therapy was not directly addressed by the consensus panel.

**Conclusion:** This document serves as preliminary guidelines until more robust evidence emerges that will support or modify these consensus recommendations. (*Plast. Reconstr. Surg.* 132: 1569, 2013.)

**N**egative-pressure wound therapy has been a widely accepted and utilized wound treatment modality for almost two decades. Although the concept of negative-pressure wound therapy had previously been described,<sup>1-3</sup> Argenta and Morykwas<sup>1</sup> were the first to systematically examine the potential of devices consisting of a highly porous polyurethane foam, a semipermeable dressing, connective tubing, and a vacuum source. Negative-pressure wound therapy has been reported to increase the rate of healing, promote wound bed granulation, prepare the wound

bed for closure, and remove exudates.<sup>1,4-9</sup> Topical irrigation solution has also been used extensively for wound bed cleansing, debris and exudate removal, and microbial eradication. Negative-pressure wound therapy with instillation combines negative pressure with a topical irrigation solution. The use of negative pressure in conjunction with instillation provides an important evolution in the negative-pressure wound therapy concept

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A Video Discussion by Mark W. Clemens, M.D., accompanies this article. Go to PRSJJournal.com and click on "Video Discussions" in the "Videos" tab to watch.

with the potential added benefit of supplying an antimicrobial solution to the wound bed.

The concepts of suction and wound irrigation are longstanding principles of surgery. Closed suction drains are commonly used to drain large cavities, thereby bringing surfaces together to allow them to heal. Wound irrigation has long been appreciated as beneficial for cleaning contaminated wounds. Svedman reported in 1979 a device that combined wound irrigation with suction that became commercially available in the early 1980s.<sup>10–13</sup> Fleischmann et al.,<sup>14</sup> in 1998, reported a gravity-fed intermittent instillation system used in conjunction with negative-pressure wound therapy. In 2003, the first commercially available negative-pressure wound therapy device with *intermittent* instillation was introduced (V.A.C. Instill Wound Therapy System; Kinetic Concepts, Inc., San Antonio, Texas). In 2007, a device with *simultaneous* irrigation was also made available (Svedman; Innovative Therapies, Inc., Gaithersburg, Md). However, neither of these devices was widely adopted by clinicians. In 2012, the next generation of negative-pressure wound therapy devices with instillation was introduced and has since rapidly gained in popularity (V.A.C. Ultra Wound Therapy System from Kinetic Concepts, and Quantum from Innovative Therapies). The majority of the consensus statements included in this article apply to the use of negative-pressure wound therapy with intermittent instillation. Devices that utilize simultaneous instillation preclude the need for some of the guidelines (e.g., dwell time and duration of negative pressure) presented in this document. Other guidelines pertaining to the type and volume of instillation solution are still relevant for simultaneous instillation.

Negative-pressure wound therapy with instillation has promise as an adjunctive therapy for contaminated or infected wounds. However, due to its novelty, there are many questions as to its effective use. The dilemma inherent in any novel therapy is the lack of evidence to support its use. There may be anecdotal evidence that suggests efficacy, but this is not sufficient in the environment of evidence-based medicine. Despite the lack of evidence for the use of novel therapies, clinicians continue to use these therapies and gain experience through trial and error. This is not an ideal method for treating patients and can result in adverse outcomes, increased health care costs, or discounting/discarding of therapies that may be effective if used appropriately. Therefore, an attempt must be made to offer some degree of guidance. Although expert opinion is considered the lowest level of evidence,

for novel therapies, expert opinion through consensus from a panel of experts can provide valuable guidance to clinicians.

The principal goal of these consensus guidelines is to address (1) the recommended uses for negative-pressure wound therapy with instillation; (2) suggested instillation solutions that can be used in negative pressure with instillation based on clinical experience; and (3) the suggested settings, including instillation dwell time and volume, duration of negative pressure, pressure settings, and duration of negative pressure combined with instillation. None of the consensus guidelines directly address the question of efficacy because of the lack of robust comparative outcome studies. It is the collective opinion of the panel that the consensus statements provide general guidelines for the most effective use of negative-pressure wound therapy with instillation, and may translate into improved clinical outcomes.

## METHODS

A multistep process was utilized to formulate the consensus guidelines. Due to the paucity of peer-reviewed publications on negative-pressure wound therapy with instillation, the consensus guidelines were based largely on agreement by the expert panelists. The peer-reviewed published literature was used as a foundation for discussion and was cited as evidence to support guideline statements whenever possible. However, due to the lack of robust, prospective, randomized, comparative, controlled studies, no formal process of evaluating the quality of the published evidence was conducted. Furthermore, the conventional consensus process (e.g., the Delphi method) was not used. Again, due to the novelty of this treatment therapy, a modified consensus process was utilized as described below.

### Panelists

Selection of the expert panelists was conducted by the lead authors (P.J.K., C.E.A., J.S.S., and K.K.E.). The 13 panelists were selected based on prior peer-reviewed publications on the topic of negative-pressure wound therapy with or without instillation, clinical experience with negative pressure with instillation, expertise in antimicrobial and antiseptic solutions, and reputation for scholarly activity. An attempt was made to capture diverse practice patterns from a variety of geographic locations as well as different specialties to create a heterogeneous expert panel sample. Panelists were selected from the United States and Germany and

encompassed the specialties of general surgery, orthopedic surgery, plastic surgery, vascular surgery, and podiatric surgery. One nonclinical panelist (G.S.) also participated in the expert panel. The nonclinical panelist's responses were not included in the consensus statements due to the clinical nature of these statements. He provided *ex vivo* and nonhuman experimental model expertise for both antibiotic/antiseptic solutions and negative-pressure wound therapy with instillation.

**Process**

Before the face-to-face meeting was convened, panelists were provided with peer-reviewed publications on the topic of negative-pressure wound therapy with instillation for review as well as with the process that would be used for consensus building. The meeting was divided into three sections. The first section consisted of presentations regarding the basic science evidence for negative-pressure wound therapy with instillation of antibiotic/antiseptic solutions. The next section focused on its clinical application as well as a review of the available peer-reviewed published evidence. The final section involved a discussion/debate about what should be included in the consensus document. Comments were digitally recorded for review by the lead authors to ensure that all viewpoints were adequately captured and reviewed. No conclusive statements were finalized at this meeting. The panelists were asked to reflect on what had been discussed, and a follow-up discussion via email and teleconference was scheduled for within the following 6 weeks.

Follow-up documents, including a list of specific consensus statements, were sent to the panelists for review and response. Panelists were asked to mark agreement or disagreement with each statement. A comments column was provided so that the panelists could add any additional remarks. Blank responses were not counted. Therefore, statements received between nine and

12 total respondents. These surveys were collated and tallied, and the results were sent back to the panelists for review and comment. An acknowledgment was provided by the panelists confirming agreement to the final consensus guidelines. A draft of the manuscript was then written by the lead authors. Panelists then made comments and suggested changes to the manuscript. The final manuscript was accepted and agreed upon by all the panelists for submission.

**Consensus Agreement**

A conventional method for reaching consensus was not utilized for these guidelines due to the novelty of this therapy. The methodology employed was a stringent agreement algorithm that combined two modified consensus-ranking approaches, the Willy and Stellar method<sup>15</sup> and the Delphi method.<sup>16</sup> The component that was used to formulate the guidelines from these two consensus models was the consensus classification schemes that provided cut-offs for consensus agreement (Table 1). The Willy and Stellar consensus scheme allowed us to evaluate the degree of agreement with a more liberal allowance for statement inclusion of greater than 50 percent. The modified Delphi classification scheme is more stringent, with more than 80 percent agreement necessary for inclusion. The results from both ranking schemes are included for review to allow readers to make their own determination as to the degree of consensus. The novelty of this consensus approach precludes the use of absolute cut-offs, because statistical inferences could not be made due to the small size of the consensus sample. However, we wanted to provide some degree of guidance specificity for the use of this novel therapy. Therefore, consensus statements contained within this document include agreement utilizing both classification schemes. The panel chose to use the modified Delphi method ranking model with a more stringent agreement

**Table 1. Consensus Ranking Scheme**

| Rank                              | Agreement              | % Agreement                      | Description                      |
|-----------------------------------|------------------------|----------------------------------|----------------------------------|
| Modified Willy and Stellar scheme |                        |                                  |                                  |
| 1                                 | Strong consensus       | >95% of participants agree       | Statement should be included     |
| 2                                 | Consensus              | >75–95% of participants agree    | Statement should be included     |
| 3                                 | Majority approval      | >50–75% of participants agree to | Statement should be included     |
| 4                                 | No consensus           | <50% of participants agree       | Statement should not be included |
| Modified Delphi method            |                        |                                  |                                  |
| 1                                 | Essential, important   | >80% of panel in agreement,      | Statement should be included     |
| 2                                 | Don't know/depends     |                                  | Statement should be excluded     |
| 3                                 | Unimportant            |                                  | Statement should be excluded     |
| 4                                 | Should not be included |                                  | Statement should be excluded     |

cut-off of more than 80 percent to generate the guideline statements included below. The results of the survey are organized in Tables 2 through 6, with the first column representing the consensus statement. The second and third columns report the tally and percentage of “yes/no” responses. The fourth and fifth columns specify the consensus rank designated by each ranking scheme. The final column indicates whether or not the guideline statement achieved consensus.

## RESULTS

The consensus statements that reached our threshold of greater than 80 percent agreement by the members of the expert panel are outlined below. There were other statements that did reach a high degree of agreement but did not meet our threshold. Exclusion of these statements does not necessarily suggest that the contents of these statements are wrong or ill-advised. Rather, the purpose of this consensus document is to provide general guidelines and not absolute principles. Table 7 provides a summary of publications to

date regarding negative-pressure wound therapy with instillation. The articles listed in Table 7 provide further support to the consensus statements.

**Consensus Statement 1:** *Negative-pressure wound therapy with instillation can be used as an adjunct therapy after appropriate wound treatment and evaluation in the following wound types: (1) acutely and chronically infected wounds, (2) contaminated wounds, (3) diabetic wounds, (4) traumatic wounds, (5) decubitus wounds, (6) wounds with exposed bone, (7) wounds with underlying osteomyelitis, (8) infected wounds in the presence of orthopedic hardware or joint implants, (8) painful wounds, and (9) wounds that are a bridge between staged/delayed amputation (Table 2).*

All wounds should be appropriately treated and evaluated. Proper wound assessment should be conducted for all wound types and address wound etiology, vascular status, and medical comorbidities. Fundamental principles of wound treatment apply, including appropriate antibiotic therapy, débridement, local wound care, and hardware/implant removal if necessary.

**Table 2. General Use Statements and Survey Results**

| Consensus Statement  | Yes          | No         | Willy and Stellar | Delphi | Consensus |
|--|--------------|------------|-------------------|--------|-----------|
| NPWT with instillation can be used as an adjunct in appropriately treated and evaluated acutely infected wounds.         | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation does not replace débridement of necrotic or infected tissue in acutely infected wounds.           | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used as an adjunct in the appropriately treated and evaluated chronically infected wounds. | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation does not replace débridement of necrotic or infected tissue in chronically infected wounds.       | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used as an adjunct in the appropriately treated and evaluated contaminated wound.          | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation does not replace débridement of the contaminated wound.   | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used for diabetic wounds.  | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used for traumatic wounds.   | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used for decubitus wounds.   | 11/12 (92%)  | 1/12 (8%)  | 2                 | 1      | Yes       |
| NPWT with instillation can be used for necrotizing fasciitis.  | 8/12 (67%)   | 4/12 (33%) | 3                 | 2      | No        |
| NPWT with instillation can be used for venous wounds.  | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used for contaminated wounds.  | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used for wounds with exposed bone.   | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used for wounds with underlying osteomyelitis.   | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used over infected orthopedic hardware (plates/screws/wires/pins).                         | 12/12 (100%) |            | 1                 | 1      | Yes       |
| NPWT with instillation can be used over infected implants (total and hemi-joint implants).                               | 11/12 (92%)  | 1/12 (8%)  | 2                 | 1      | Yes       |
| NPWT with instillation can be used for painful wounds.   | 10/12 (83%)  | 2/12 (17%) | 2                 | 1      | Yes       |
| NPWT with instillation can be used in the interim between a staged/delayed amputation.                                   | 10/11 (91%)  | 1/11 (9%)  | 2                 | 1      | Yes       |
| NPWT with instillation can be used for abdominal cavity wounds.  | 6/9 (67%)    | 3/9 (33%)  | 3                 | 2      | No        |

NPWT, negative-pressure wound therapy.



**Table 3. Instillation Solution Statements and Survey Results**

| Consensus Statement   | Yes          | No         | Willy and Stellar | Delphi | Consensus |
|---|--------------|------------|-------------------|--------|-----------|
| An appropriate instillation solution is <b>Lavasept</b> (polyhexanide 0.04%).   | 12/12 (100%) |            | 1                 | 1      | Yes       |
| An appropriate instillation solution is <b>Prontosan</b> (polyhexanide 0.1% plus betaine).                                | 12/12 (100%) |            | 1                 | 1      | Yes       |
| An appropriate instillation solution is Dakin's solution (0.125% sodium hypochlorite).                                    | 7/12 (58%)   | 5/12 (42%) | 3                 | 4      | No        |
| An appropriate instillation solution is diluted acetic acid 0.25%.  | 5/12 (42%)   | 7/12 (58%) | 4                 | 4      | No        |
| An appropriate instillation solution is diluted acetic acid 1.0%.   | 9/12 (75%)   | 3/12 (25%) | 3                 | 2      | No        |
| An appropriate instillation solution is silver nitrate.   | 4/12 (33%)   | 8/12 (67%) | 4                 | 2      | No        |
| An appropriate instillation solution is Nebacetin (neomycin sulfate/bacitracin) plus Lavasept (polyhexanidum/macrogolum). | 5/12 (42%)   | 7/12 (58%) | 4                 | 2      | No        |
| An appropriate instillation solution is Microcyn/Dermacyn (superoxidized water).  | 8/9 (89%)    | 1/9 (12%)  | 2                 | 1      | Yes       |
| An appropriate instillation solution is <b>diluted iodine</b> .   | 5/12 (42%)   | 7/12 (58%) | 4                 | 4      | No        |
| An appropriate instillation solution is 1% or 2% lidocaine mixed with antibiotic solution.                                | 5/10 (50%)   | 5/10 (50%) | 3                 | 2      | No        |
| An appropriate instillation solution is 1% or 2% lidocaine mixed with Dakin's solution (0.125% sodium hypochlorite).      | 4/12 (33%)   | 8/12 (67%) | 4                 | 4      | No        |
| An appropriate instillation solution is normal saline.  | 6/11 (55%)   | 5/11 (45%) | 3                 | 4      | No        |

Negative-pressure wound therapy with instillation should not be used as a sole modality to treat infection.

Negative pressure with instillation has been used successfully in various types of infected wounds in many different locations on the body, including the extremities, breast, torso, abdomen, buttocks, and sacrum.<sup>11,14,17-26</sup> It has been used

in particularly challenging cases as well. Gabriel et al.,<sup>17</sup> Lehner et al.,<sup>20</sup> and others<sup>21-26</sup> report that it has been used effectively in the environment of osteomyelitis, exposed hardware, and infected orthopedic implants. However, use of negative pressure with instillation has not been approved in the United States for wounds with infected orthopedic implants. The treatment has also been used

**Table 4. Negative-Pressure Wound Therapy with Instillation Settings Statements and Survey Results**

| Consensus Statement   | Yes         | No          | Willy and Stellar | Delphi | Consensus |
|---|-------------|-------------|-------------------|--------|-----------|
| An appropriate instillation dwell time is less than 1 minute.   | 4/11 (36%)  | 7/11 (64%)  | 4                 | 2      | No        |
| An appropriate instillation dwell time is 5 minutes.  | 6/12 (50%)  | 6/12 (50%)  | 3                 | 2      | No        |
| An appropriate instillation dwell time is 10 minutes.   | 11/12 (92%) | 1/12 (8%)   | 2                 | 1      | Yes       |
| An appropriate instillation dwell time is 20 minutes.   | 10/11 (91%) | 1/11 (9%)   | 2                 | 1      | Yes       |
| An appropriate instillation dwell time is 30 minutes.   | 5/12 (42%)  | 7/12 (58%)  | 4                 | 4      | No        |
| An appropriate instillation dwell time is 60 minutes.   | 2/12 (17%)  | 10/12 (83%) | 2                 | 1      | Yes       |
| An appropriate instillation dwell time is greater than 60 minutes.  | 1/12 (8%)   | 11/12 (92%) | 2                 | 1      | Yes       |
| An appropriate volume of instillation used is until the foam is visibly saturated.  | 10/12 (83%) | 2/12 (17%)  | 2                 | 1      | Yes       |
| An appropriate volume of instillation used is 5 ml.   | 1/10 (10%)  | 9/10 (90%)  | 4                 | 4      | No        |
| An appropriate volume of instillation used is 10 ml.  |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is 15 ml.  |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is 20 ml.  |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is 30 ml.  |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is 40 ml.  |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is 50 ml.  |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is 75 ml.  |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is 100 ml.   |             | 9/9 (100%)  | 1                 | 1      | Yes       |
| An appropriate volume of instillation used is dependent on wound volume and the instillation volume should match this wound volume.       | 9/12 (75%)  | 3/12 (25%)  | 3                 | 2      | No        |
| An appropriate volume of instillation used is dependent on wound volume and the instillation volume should be less than the wound volume. | 9/12 (75%)  | 3/12 (25%)  | 3                 | 2      | No        |

**Table 5. Negative-Pressure Wound Therapy Settings Statements and Survey Results**

| Consensus Statement                                  | Yes          | No           | Willy and Stellar | Delphi | Consensus |
|--|--------------|--------------|-------------------|--------|-----------|
| An appropriate NPWT time is 30 minutes.              | 6/11 (55%)   | 5/11 (45%)   | 3                 | 2      | No        |
| An appropriate NPWT time is 1 hour.                  | 10/11 (91%)  | 1/11 (9%)    | 2                 | 1      | Yes       |
| An appropriate NPWT time is 2 hours.                 | 10/12 (83%)  | 2/12 (17%)   | 2                 | 1      | Yes       |
| An appropriate NPWT time is 2.5 hours.               | 10/11 (91%)  | 1/11 (9%)    | 2                 | 1      | Yes       |
| An appropriate NPWT time is 3 hours.                 | 8/11 (73%)   | 3/11 (27%)   | 3                 | 2      | No        |
| An appropriate NPWT time is 3.5 hours.               | 8/11 (73%)   | 3/11 (27%)   | 3                 | 2      | No        |
| An appropriate NPWT time is 4 hours.                 | 8/11 (73%)   | 3/11 (27%)   | 3                 | 2      | No        |
| An appropriate NPWT pressure setting is -125 mmHg.   | 12/12 (100%) |              | 1                 | 1      | Yes       |
| An appropriate NPWT pressure setting is -150 mmHg.   | 10/12 (83%)  | 2/12 (17%)   | 2                 | 1      | Yes       |
| An appropriate NPWT pressure setting is -200 mmHg.   | 2/12 (17%)   | 10/12 (83%)  | 2                 | 1      | Yes       |
| An appropriate NPWT pressure setting is -250 mmHg.   | 1/12 (8%)    | 11/12 (92%)  | 2                 | 1      | Yes       |
| An appropriate NPWT pressure setting is -275 mmHg.   |              | 12/12 (100%) | 1                 | 1      | Yes       |
| An appropriate NPWT pressure setting is -300 mmHg.   |              | 12/12 (100%) | 1                 | 1      | Yes       |
| An appropriate NPWT pressure setting is -400 mmHg.   |              | 12/12 (100%) | 1                 | 1      | Yes       |
| An appropriate NPWT pressure setting is -500 mmHg.   |              | 12/12 (100%) | 1                 | 1      | Yes       |
| NPWT pressure should be set on continuous setting.   | 11/12 (92%)  | 1/12 (8%)    | 2                 | 1      | Yes       |
| NPWT pressure should be set on intermittent setting. | 4/12 (33%)   | 8/12 (67%)   | 3                 | 2      | No        |

NPWT, negative-pressure wound therapy.

successfully for abdominal wounds with exposed polypropylene or biological mesh.<sup>27</sup> It is important to emphasize that negative-pressure wound therapy with instillation should not be used as a substitute for appropriate medical and surgical care.

**Consensus Statement 2:** *Negative-pressure wound therapy with instillation does not replace débridement of the acutely infected, chronically infected, or contaminated wound (Table 2).*

Negative-pressure wound therapy with instillation is *not* a débridement modality. The accepted standard for the treatment of an infected or contaminated wound is excisional débridement with irrigation.<sup>28-31</sup> However, negative pressure with instillation can help facilitate the removal of debris, reduce contamination, expedite infection clearance, and decrease infection recurrence.<sup>17,18,20,32</sup> For example, a patient may have

**Table 6. Negative-Pressure Wound Therapy with Instillation Duration Statements and Survey Results**

| Consensus Statement   | Yes        | No          | Willy and Stellar | Delphi | Consensus |
|---|------------|-------------|-------------------|--------|-----------|
| An appropriate minimum duration of NPWT with instillation is 1 day.   | 5/12 (42%) | 7/12 (58%)  | 4                 | 2      | No        |
| An appropriate minimum duration of NPWT with instillation is 2 days.  | 8/12 (67%) | 4/12 (33%)  | 3                 | 2      | No        |
| An appropriate maximum duration of NPWT with instillation is 2 days.  | 4/12 (33%) | 8/12 (67%)  | 4                 | 2      | No        |
| An appropriate maximum duration of NPWT with instillation is 5 days.  | 6/12 (50%) | 6/12 (50%)  | 4                 | 2      | No        |
| An appropriate maximum duration of NPWT with instillation is 10 days. | 5/12 (42%) | 7/12 (58%)  | 4                 | 2      | No        |
| An appropriate maximum duration of NPWT with instillation is 15 days. | 4/12 (33%) | 8/12 (67%)  | 4                 | 2      | No        |
| An appropriate maximum duration of NPWT with instillation is 20 days. | 2/12 (17%) | 10/12 (83%) | 2                 | 1      | Yes       |
| An appropriate maximum duration of NPWT with instillation is 25 days. | 1/12 (8%)  | 11/12 (92%) | 2                 | 1      | Yes       |
| An appropriate maximum duration of NPWT with instillation is 30 days. | 1/12 (8%)  | 11/12 (92%) | 2                 | 1      | Yes       |
| An appropriate maximum duration of NPWT with instillation is 40 days. | 1/12 (8%)  | 11/12 (92%) | 2                 | 1      | Yes       |
| An appropriate maximum duration of NPWT with instillation is 50 days. | 1/12 (8%)  | 11/12 (92%) | 2                 | 1      | Yes       |
| An appropriate maximum duration of NPWT with instillation is 60 days. | 1/12 (8%)  | 11/12 (92%) | 2                 | 1      | Yes       |
| There is no appropriate minimum duration of NPWT with instillation.   | 4/12 (33%) | 8/12 (67%)  | 3                 | 2      | No        |
| There is no appropriate maximum duration of NPWT with instillation.   | 5/12 (42%) | 7/12 (58%)  | 3                 | 2      | No        |

NPWT, negative-pressure wound therapy.

**Table 7. Summary of Pertinent Publications Related to Negative-Pressure Wound Therapy with Instillation**

| Study   | Wound Type   | Instillation Solution   | Dwell Time (min)                                  | NPWT Time (min) | Negative Pressure Setting (mmHg) | Instillate Volume (ml) | Duration of Application (days) |
|---|--|---|---|-----------------|----------------------------------|------------------------|--------------------------------|
| Fleischmann et al. (1998), <sup>14</sup> case series                  | Acute infection, chronic osteomyelitis (n = 27)        | Alternating Nebacetin (neomycin sulfate/bacitracin) and Lavasept (polyhexanidum/macrogolum)   | 30  | 180             | 50–600                           | ?                      | 33.5 (30–37)                   |
| Wolvos (2004), <sup>21</sup> case series                              | Acute and chronic infections (n = 5)                   | 1%, 2% Lidocaine, bacitracin, cefazolin, Dakin's solution, gentamycin, tobramycin, vancomycin | 5   | 180             | 125                              | ?                      | 15 (5–24)                      |
| Bernstein and Tam (2005), <sup>22</sup> case series                   | Postsurgical diabetic foot wounds (n = 5)              | Saline, polymyxin B, bacitracin   | 5   | 360             | 125                              | ?                      | 2–9                            |
| Timmers et al. (2009), <sup>18</sup> retrospective case-control study | Posttraumatic osteomyelitis (n = 30); control (n = 94) | Lavasept (polyhexanide 0.04%)   | 10–15   | ?               | 300–600                          | 3–10                   | 24 (6–60)                      |
| Gabriel et al. (2008), <sup>17</sup> retrospective case-control study | Acute infection (n = 15); control (n = 15)             | Silver nitrate  | 30- to 45-second instillation with 1-second dwell | 120             | 125                              | 50–75                  | 9.8 (5–20)                     |
| Schintler et al. (2009), <sup>23</sup> case series                    | Acute infection (n = 15)                               | Lavasept (polyhexanide 0.04%)   | 20  | ?               | ?                                | ?                      | 4–18                           |
| Lehner et al. (2009), <sup>26</sup> case series                       | Infection in periorthopedic implants (n = 23)          | Lavasept (polyhexanide 0.04%)   | 15  | 60              | 125                              | ?                      | ?                              |
| Leffler et al. (2009), <sup>24</sup> case series                      | Chronic osteomyelitis (n = 6)                          | Lavasept (polyhexanide 0.04%)   | 20  | 180–360         | ?                                | ?                      | ?                              |
| Koster (2009), <sup>25</sup> case series                              | Infection in periorthopedic implants (n = 10)          | Lavasept (polyhexanide 0.04%)   | 10–15   | 45–60           | ?                                | ?                      | 3–9                            |
| Raad et al. (2010), <sup>19</sup> case series                         | Chronic venous wounds (n = 5)                          | Dakin's solution (0.125% sodium hypochlorite)   | 10  | 50              | ?                                | ?                      | 10                             |
| Lehner et al. (2011), <sup>20</sup> case series                       | Infection in periorthopedic implants (n = 32)          | Lavasept (polyhexanide 0.04%)   | 5–30  | 70.3 (30–270)   | 125–200                          | ?                      | 16.3 (9–46)                    |

a grossly infected wound that requires serial débridement. Negative-pressure wound therapy with instillation can be used as a bridge between débridements to prepare the wound bed for closure or grafting.

**Consensus Statement 3:** *The following are appropriate instillation solutions that can be used with negative-pressure wound therapy with instillation: (1) Lavasept (polyhexanide 0.04%), (2) Prontosan (polyhexanide 0.1% plus betaine), and (3) Microcyn/Dermacyn (Table 3).*

Selection of the appropriate solution may be a critical piece in maximizing the benefit of negative-pressure wound therapy with instillation. However, solutions discussed below have not been cleared by the FDA as antimicrobial products. Many solutions have been used for instillation. Both Lavasept (B. Braun, Inc., Bethlehem, Pa.) and Prontosan (B. Braun) contain polyhexamethylene biguanide, which has shown broad-spectrum antimicrobial activity.<sup>33–36</sup> Prontosan contains an added component of 0.1% betaine, a surfactant

that has been reported to cause more than 5-log bacterial growth reduction in vitro.<sup>37</sup> The combination of an antimicrobial and a surfactant may have the increased benefit of dissolving biofilm and is well tolerated.<sup>36,38,39</sup> Lee et al.<sup>40</sup> reported that polyhexamethylene biguanide is particularly effective in inhibiting Gram-positive bacterial growth but has less efficacy against Gram-negative bacteria in an in vitro model. Polyhexamethylene biguanide has been reported to be as effective as chlorhexadine in decreasing a particularly resistant *Pseudomonas aeruginosa* biofilm.<sup>41</sup> Negative-pressure wound therapy with polyhexamethylene biguanide solution has been used effectively as an adjunct therapy for infections in the environment of osteomyelitis and periprosthetic infections, with an implant salvage rate greater than 80 percent.<sup>18,20,24-26</sup>

Microcyn (Oculus Innovative Sciences, Petaluma, Calif.) and Dermacyn (Oculus Innovative Sciences) are composed of neutral-pH electrolyzed/superoxidized water with hypochlorous acid (dissolved chlorine in water). Microcyn wound irrigation has been reported to be as effective as oral levofloxacin in the treatment of mild diabetic foot wound infections.<sup>42</sup> Goretti et al.<sup>43</sup> reported decreased infection recurrence rates in postsurgical diabetic foot ulcers using daily Dermacyn irrigation as compared with povidone iodine. Similar to polyhexamethylene biguanide, Microcyn has been reported to produce a greater than 3-log reduction in *P. aeruginosa* biofilm and an 8-log reduction in *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans* in the in vitro model.<sup>44,45</sup> Microcyn and Dermacyn have been used effectively and safely as the solution of choice for negative-pressure wound therapy with instillation.<sup>27</sup>

Although the above solutions received the highest level of consensus, other instillation solutions have been used by the expert panel, notably 0.25% and 1% diluted acetic acid, diluted iodine, and 0.125% sodium hypochlorite (Dakin's solution). Furthermore, antibiotics alone, as well as cocktails utilizing antibiotics mixed with local anesthetics (1%, 2% lidocaine plain), have been used to address painful wounds.<sup>14,21,22</sup> The toxicity levels, for both the antibiotic and local anesthetic, have not been thoroughly studied for this type of mixed solution. Normal saline has also been used for instillation. Negative-pressure wound therapy with normal saline instillation has been reported to potentiate granulation tissue formation at a higher rate in the acute excisional porcine wound model.<sup>46</sup> Silver nitrate solution has also been used in conjunction with negative-pressure wound

therapy. Gabriel et al.<sup>17</sup> reported a significant difference in the percentage of Gram-positive bacterial infection clearance for negative-pressure wound therapy and silver nitrate instillation as compared with wet-to-moist wound dressings. Silver nitrate should be handled with care due to its toxic and corrosive characteristics and must be protected from exposure to light. Therefore, this solution may not be practical for frequent use. It is important to consider the goals of the therapy when selecting an instillation solution, taking into account the solution's potential toxicity, activity, availability, and cost.

**Consensus Statement 4:** *An appropriate range of instillation dwell time is 10 to 20 minutes (Table 4).*

The dwell (soak) refers to the length of time the instillation solution is in contact with the wound bed when negative pressure is not being applied. A balance must be struck between dwell time and the length of time in which negative pressure is applied. A longer dwell time results in a shorter period of time when the wound experiences negative pressure. Shorter negative pressure times may result in decreased positive effects of negative pressure on the wound bed. A longer dwell time may result in a higher risk of surrounding tissue maceration or instillation solution leaks.

The optimal dwell time is not clear in the published literature (Table 7). In vitro evidence evaluating the effect of various antimicrobial/antiseptic solutions on various types of bacteria and yeast suggests that longer contact times (>10 minutes) result in decreased microbial counts.<sup>47,48</sup> However, there is currently no evidence that evaluates dwell time and its relationship to antimicrobial activity when a solution is used in combination with negative-pressure wound therapy.

**Consensus Statement 5:** *An appropriate volume of instillation solution used is until the foam is visibly saturated (Table 4).*

The ideal volume of instillation solution is particularly elusive due to wound size variations complicated by tunneling and irregular dimensions. Too much solution may cause difficulty in maintaining a seal with the occlusive dressing and could cause maceration of the surrounding tissue. Insufficient volume will not allow enough solution to bathe the entire wound surface. Therefore, a recommendation for an absolute volume of solution is not possible. The recommendation of this panel is to monitor the foam until it is completely saturated (indicated by a darker color change) and begins to raise the occlusive dressing.

**Consensus Statement 6:** *An appropriate negative pressure time phase is 1 to 2.5 hours (Table 5).*





There is variability in the length of time that negative pressure should be applied to the wound surface. The minimum or maximum length of time is still undetermined. The novelty of the negative-pressure wound therapy with instillation technology is the combined benefit of negative pressure and instillation of a solution. Ideally, you do not want to compromise the positive effects of either component. Beyond the well-established beneficial effects of negative pressure, there may also be additional antimicrobial effects as well. Ngo et al.<sup>49</sup> reported that in an in vitro *P. aeruginosa* biofilm model, negative pressure alone may have a significant inhibitory impact on biofilm. Thus, the combination of negative pressure with a solution may have an additive antimicrobial effect. For large wounds, negative pressure times can lead to frequent solution exchange, emptying of the container, and placement of the new solution container, which may lead to compliance issues.

**Consensus Statement 7:** *An appropriate pressure setting for negative-pressure wound therapy with instillation is -125 mmHg and -150 mmHg (Table 5).*

There is no need to deviate from the standard settings for negative-pressure wound therapy. There was strong agreement among the consensus panelists that negative pressures greater than 200 mmHg are not necessary. Morykwas et al.<sup>50,51</sup> suggested that pressures that are lower or higher than 125 mmHg result in a significant decrease in formulation of granulation tissue. However, Timmers et al.<sup>18</sup> reported the use of negative pressures ranging from 300 to 600 mmHg when utilizing negative pressure with instillation. They reported a significant difference in the recurrence of infection (10 percent versus 58.5 percent), number of surgical procedures (two versus five), and length of hospital stay (36 days versus 73 days) in the negative pressure with instillation group compared with the patients who received standard care. It is important to note that in this report, the investigators utilized a hydrophobic foam (polyvinyl alcohol) rather than the more commonly used hydrophilic foam. Despite this single, small, retrospective study, the majority of published studies indicate that a negative pressure around 125 mmHg is sufficient to produce positive results (Table 7). Although there is a single report<sup>14</sup> of using negative pressure settings below 125 mmHg with instillation, the panelists were in agreement that lower settings may result in suboptimal effects on the wound bed as described by Morykwas et al.<sup>50,51</sup> Therefore, negative pressures below 125 mmHg were not included as part of the consensus survey.

**Consensus Statement 8:** *An appropriate setting for negative pressure is continuous, not intermittent (Table 5).*

This statement refers to the period when negative pressure is applied. It has been reported that intermittent negative pressure is more beneficial to the wound bed than continuous negative pressure.<sup>51,52</sup> The consensus panel, as well as the published literature on negative pressure with instillation, is in agreement that continuous pressure is the preferred method for several reasons (Table 7). Obviously, negative-pressure wound therapy is interrupted during dwell times. Therefore, some degree of intermittence is inherent. As a practical matter, there may be concern about the more frequent release of suction during continuous negative pressure, which increases the chance of loss of a seal with the occlusive dressing. This may lead to the increased possibility of maceration to the surrounding tissue as well increased time spent troubleshooting leaks.

**Consensus Statement 9:** *The exact minimum and maximum durations of negative pressure wound therapy with instillation vary (Table 6).*

There are no absolute minimum or maximum durations for the use of negative-pressure wound therapy with instillation. Duration of therapy depends on the goals of therapy, including control of bacteria and wound bed preparation for wound closure. Negative pressure with instillation for less than 1 day may not be a good use of this type of treatment due to the short duration. Furthermore, indefinite use is also not clinically or economically prudent. Generally, negative pressure with instillation may be used until the wound is deemed ready for the next stage of treatment, which may be closure, grafting, or healing through secondary intention. Sound clinical judgment should be used to determine the total duration of therapy.

## DISCUSSION

The guidelines presented in this consensus document provide a general framework for the use of negative-pressure wound therapy with instillation. Although peer-reviewed publications were used whenever available to support the consensus statements, this article should not be viewed as an evidence-based approach. Precisely because there is a paucity of evidence for the use of negative-pressure wound therapy with instillation, a consensus panel composed of experts on this topic was convened, with the results presented in this article. There are obvious limitations to using a consensus panel, particularly the relatively small

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number of panelists. As noted in the Methods section, a rigorous consensus-building process such as the Delphi method was not undertaken. Such a process provides the ability to distill essential statements on which a large majority can agree. Panel members brought their unique clinical biases based on their individual experiences, which influenced the consensus statements. During the face-to-face meeting, these biases may have influenced other members to conform by providing a convincing argument favoring their opinion. A robust consensus panel consists of a large number of panelists in order to dilute individual preferences that are potentially outliers. These outliers would significantly influence the calculation for consensus, which would be especially true in our case due to the limited number of panelists. The statements contained in this document reflect those that persisted despite the influence of outliers. Hence, having a limited number of panelists can be viewed as a strength rather than a weakness.

The statements contained within this document provide a minimal set of guidelines for the use of negative-pressure wound therapy with instillation. To our knowledge, this is the first consensus document attempting to better define the use of negative pressure with instillation. This adjunctive modality holds promise in the treatment of challenging wounds due to its dual benefit of negative pressure and instillation of an antimicrobial solution. Modification of this consensus document will be required as knowledge is accumulated through robust peer-reviewed publications. With a growing body of evidence, further refinement of the parameters for using negative pressure wound therapy with instillation will be established.

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