Wound Debridement

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Introduction

The word debridement first came from the French *desbrider*, meaning, “to unbridle.” It was probably first used as a medical term by surgeons working several hundred years ago in war zones, who recognized that grossly contaminated soft-tissue wounds had a better chance of healing if the affected tissue was surgically removed.1

Wound debridement has evolved and is now recognized as a key component of preparing a wound bed for healing.2–7 The presence of necrotic or devitalized tissue on the surface of a wound prevents accurate assessment of the extent of tissue destruction, inhibiting clinicians’ abilities to correctly stage or classify wounds using standard assessment tools.

During the normal cascade of events leading to wound repair, inflammatory cells, such as neutrophils and macrophages, are activated to remove devitalized tissue, participate in antimicrobial defense, and facilitate the beginning of the repair process. The alteration in this and subsequent cellular activities creates an environment leading to wound chronicity and, ultimately, a milieu of increasing necrotic burden.

The term *necrotic burden* has been frequently used to describe dead or devitalized tissue, excess exudate, and high levels of bacteria found on the surface of many chronic, non-healing wounds. In addition to the evident nonviable tissue, resident cells, such as fibroblasts and keratinocytes, may be phenotypically altered and no longer responsive to certain signals, including growth factors. This state is described by the term *cellular senescence.7,8*

Necrotic or devitalized tissue impedes wound management and healing in several ways:

- Devitalized tissue may mask or mimic signs of infection
- Necrotic tissue serves as a source of nutrients for bacterial cells, thus contributing to the risk of critical colonization or infection
- Devitalized tissue acts as a physical barrier to healing and may impede normal matrix formation, angiogenesis, or granulation tissue development and epidermal resurfacing
- The presence of necrotic or devitalized tissue contributes to the stimulus to produce inflammatory cytokines leading to the overproduction of matrix metalloproteases (MMPs).7–9

The Decision to Debride

The overall condition of the patient and individual goals of care must be considered in the decision to debride. In most cases, a terminally ill patient with an intact eschar would not be a candidate for debridement. The result of such an action may be a larger, potentially more painful wound requiring more extensive topical care with little-to-no opportunity for healing due to the patient’s severely compromised condition. The patient’s general state of health, nutritional status, and medications must also be considered. The patient on anticoagulants, for example, may need to be debrided with a less invasive technique than sharp or surgical debridement or would be more safely debrided in a controlled setting, such as the operating room or hospital clinic, than at the bedside, in the home, or in the long-term care setting. Furthermore, access to adequate anesthesia, whether topical, regional, or general, must be considered for all patients with wounds in sensate areas.

Most chronic wounds require some type of debridement. Debridement is not just a singular event; rather, it is a combination of modalities to achieve a clean, healthier wound bed, as well as a repeated intervention to continuously stimulate and revive the surface cells, keeping the wound in a state of “readiness to heal.”9 Chronic wounds have underlying pathogenic abnormalities that cause necrotic tissue to form and the necrotic/cellular burden to accumulate. To manage this recognized impediment to wound healing, the practice standard of “maintenance” debridement is recognized and accepted. This includes repeated debridement sessions that continue until the wound can sustain a healthy functional wound bed.2 Steed et al9 found that diabetic foot ulcers that were debrided sharply on a routine basis healed more consistently than ulcers that were not well debrided and maintained.

The decision to debride should be carefully considered in certain wound etiologies. Prior to performing debridement of any type in the lower extremity, vascularity must be assessed. Stable, noninfected heel or lower-extremity ulcers in the presence of impaired circulation10 usually should not be debrided unless they show signs of infection (erythema, fluctuance, separation from the edge with drainage, purulence)11 (Plates 12–14, Page 346). Palpating the pedal pulse of patients with lower-extremity wounds is inadequate to assess blood flow. Patients with diabetes who have lower-extremity wounds may need formal noninvasive assessment (digital toe pressures and wave forms, transtutaneous oxygen studies, or ultrasound arterial evaluations) to determine blood flow due to the propensity of the more proximal vessels to calcify. Maintaining a dry, stable eschar often leads to the eschar demarcating and separating slowly as epithelial migration occurs from the edge. With certain etiologies, such as pyoderma gangrenosum, it is well known that debridement may actually result in a worsening of the wound or pathergy.

Types of Debridement

Globally, debridement falls into 2 categories, selective and nonselective.12 With selective debridement, only nonviable tissue is removed, while with nonselective techniques, both viable and nonviable tissue may be targeted. Debridement is also commonly classified or categorized by the method or the mechanism of action of the various techniques utilized to eliminate abnormal tissue from the wound bed.

The types of debridement currently used in clinical practice include sharp (instrument/surgical, laser, and hydrosurgical), mechanical (whirlpool, pulsed lavage, and low-frequency ultrasound), enzymatic, autolytic, and biotherapy or maggot debridement therapy (MDT). Clinicians may choose 1 or a combination of 2 or
more methods over the course of the management of a wound to achieve and maintain a clean wound bed.

**Sharp**

Sharp debridement refers to the use of instruments or devices capable of excising or cutting away necrotic tissue and surface debris (Plate 15, Page 346). The instruments include, but are not limited to, forceps or pickups, scalpels, curettes, scissors, and rongeurs. While the instruments may be disposable or reusable, those found in the average suture-removal kit are generally not strong or sharp enough to adequately accomplish wound debridement. Further, sharp debridement may be accomplished using devices, such as the laser or high-powered parallel waterjet (Versajet®, Smith & Nephew, Largo, Fla).

**Instrument Debridement**

Sharp instrument debridement is a fast method of removing the necrotic burden. This intervention can often achieve a clean wound base in one treatment, particularly if the procedure is performed in the operating room. Conservative sharp debridement may also be performed in serial sessions, potentially combined with another form of debridement ultimately resulting in a clean wound.

The clinician performing instrument debridement should have adequate training and skill competencies. The practitioner’s basic healthcare training does not necessarily indicate adequate competency to perform instrument debridement. Certain physicians, such as surgeons and podiatrists, are the best prepared. Others, particularly nurses, physical therapists, and physician extenders, such as nurse practitioners and physician assistants, should undergo additional didactic and skills lab training, plus a further hands-on preceptorship, before performing routine sharp debridement. Evidence of completion of such training should be maintained in the clinician’s employee file. Knowledge of one’s particular licensure practice act is paramount before performing this procedure. Some states prohibit certain levels of healthcare practitioners from performing debridement of living tissue and restrict their practice to the debridement of devitalized tissue. Clarification of the limitations on your professional practice by your state-specific practice board is reasonably prudent practice.

As previously mentioned, many chronic wounds require maintenance debridement, even if the wound has been surgically prepared previously. This is typically accomplished with sharp instruments, such as a curette, and is minimally excisional by removing the immediate wound surface. The goal is always to enhance wound healing by reducing or eliminating bacteria and biofilms, as well as senescent cells. Additionally, maintenance debridement enables the clinician to assess and address the wound edges. Epiboly, or the growth of keratinocytes down the edge of a wound, results in a closed wound edge with cells less likely or unable to migrate out and resurface the wound.

The patient must be adequately prepared for sharp debridement. Informed consent should be obtained, particularly if operative debridement will be performed. The facility or agency protocol will dictate consent policies that should be followed. Prior to sharp/surgical debridement, the wound site should be prepared by adequate cleansing to remove exudate, residue, and any loose debris, which may have accumulated since the previous dressing change. The choice to use an antimicrobial cleanser or solution depends on the presence or absence of infection, the appearance of surface contamination or presumed colonization, and the patient’s own host defenses. Because transient local bacteremia may occur with sharp/surgical debridement, the immunocompromised patient may be best managed with prophylactic systemic antibiotics in preparation for the procedure.

Adequate pain management before, during, and after the procedure is imperative. Premedication can help to reduce anxiety and discomfort related to cleansing and preparing the wound for debridement. Topical or local anesthetics should be employed after adequate cleansing to reduce or eliminate procedural pain. Lastly, the practitioner needs to plan for post-procedural pain with adequate orders for pain control after the procedure is completed. For further information, see Chapter 9.

Patients must understand the reason for the sharp/surgical debridement. The clinician should keep in mind that, to the average person, scabs are
good and are to be left alone. To enhance patient cooperation and decrease anxiety during procedures, a non-rushed explanation of basic wound-bed preparation at the patient’s level of comprehension should be undertaken. Describing the difference between a scab and necrotic tissue and the detrimental effects of the necrotic tissue to overall wound healing will assist patients in understanding why they will benefit from debridement. Lastly, patients must feel that they are in control. Assure them that if the procedure is too painful and they are unable to tolerate the discomfort, the procedure will be stopped. This will go a long way toward establishing patient trust and willingness to consent to future procedures.

The decision to perform sharp surgical debridement in the operating room is largely based on the extent and depth of the anticipated debridement and the need to accomplish the procedure under controlled conditions (pain, bleeding, asepsis). Other factors may include:

- Emergent procedures, such as in the case of infected wounds or patient sepsis
- The need for a higher degree of asepsis, such as with the presence or potential presence of tendon, bone, or joints
- The need for extensive bone debridement
- The need for adequate anesthesia
- Wounds involving extensive undermining, sinus tracts, or tunneling
- The potential for excessive bleeding
- The patient's anxiety or stress related to the procedure.

In addition to the use of instruments, the operating room provides an environment for the use of devices that accomplish debridement into deeper tissues more rapidly than with instruments. These include the use of laser and the high-powered waterjet.

**Laser Debridement**

The term laser is an acronym for light amplification by the stimulated emission of radiation. Laser debridement, a form of surgical sharp debridement, uses focused beams of light to cauterize, vaporize, or slice through tissue. It is an operative procedure that likely is used less frequently than other forms of debridement.

There are several light sources available for lasers: argon, CO₂, neodymium yttrium aluminum garnet (Nd:YAG), and tunable. The emission of light at different wavelengths enables the laser to target different types of body tissues, depending on the part of the tissue that absorbs the light. When laser energy hits tissue, ablation occurs. The intense heat of laser light causes water within a cell to boil. After the water boils, it expands and ruptures the cell wall, vaporizing the cell contents and creating a small amount of steam as a by-product.

Water readily absorbs CO₂ laser energy, which makes this kind of laser energy inefficient in fluid-filled cavities. CO₂ energy, however, is considered one of the most efficient and precise cutting lasers on the market. The argon laser works best on pigmented tissue and is absorbed easily within the hemoglobin-rich retinal surface. The contact YAG lasers are better at coagulation than other lasers, such as the CO₂ laser, which only works on smaller vessels and, therefore, would be ineffective in controlling significant bleeding. Different laser sources are used in different situations depending on the type of tissue involved, extent of the necrosis, location of the wound, and the goal of the procedure. Due to the potential risk of injury to adjacent tissue, the use of laser energy for debridement is a highly skilled procedure not available in all settings. Newer work with pulsed versus continuous laser beams has reduced the risk of negative effects.

**Hydrosurgical Debridement**

The high-powered parallel waterjet (Versajet®) is a newer surgical debridement tool that precisely removes tissue using a high-energy water beam. This US Food and Drug Administration (FDA)-approved medical device has the ability to focus a high-powered stream of water into a high-energy cutting implement. The saline used in the waterjet is enclosed in a sterile circuit that passes through a small but highly powerful pump. The saline is directed through high-pressure tubing into a hand piece where it is directed into a 180-degree turn and forced through a nozzle 0.005” in diameter. The energized saline emerges in a focused beam of up to 15,000 psi. The saline beam is directed parallel to the wound so that the cutting mechanism is a highly controlled form of tangential excision. If the handset is positioned in an oblique position, irrigation and tissue removal
are accomplished. The surgeon can further regulate the excising effect of the waterjet by adjusting its pressure and velocity via 10 power settings. As the water speed increases, the excising effect on the unwanted tissue increases. This cutting action provides the surgeon control over the wound surface.14,15

This form of surgical debridement is reported to be less effective in pressure ulcers covered with dry eschar. The preferred approach is to sharply remove the eschar and then use the waterjet to debride the underlying necrotic tissue. Consequently, all of the necrotic tissue, fibrinous debris, and granulation tissue can be removed with no injury to the healthy underlying collateral tissue. Surgeons can perform more aggressive wound debridement while simultaneously removing less surrounding tissue.14,15 Granick et al14 reported improved patient outcomes, fewer required surgeries, and lower costs related to achieving a well-prepared wound bed for more rapid time to surgical closure or application of effective topical therapies (Plate 16, Page 346).

**Mechanical Debridement**

The term mechanical debridement refers to the use of some external force to dislodge and remove debris and necrotic burden from the wound surface. Because of the nature of the mechanical force, this method is considered to be primarily nonselective. Mechanical methods include various forms of hydrotherapy, wet-to-dry or wet-to-moist dressings, and low-frequency ultrasound.

**Hydrotherapy**

Hydrotherapy, the use of fluids for cleansing and debridement, includes whirlpool, pulsatile lavage with suction, irrigation, and jet lavage.

**Whirlpool**

Whirlpool is considered a nonspecific form of mechanical debridement that facilitates cleansing by immersing the patient’s body part in a tub or tank while a turbine agitates the water. Whirlpool treatment is no longer a highly favored mechanical debridement treatment modality for a variety of reasons. The risk of infection from cross-contamination and aerosolization are dangers that must be considered.5

In most instances, whirlpool is an inappropriate modality for chronic venous insufficiency leg ulcers and diabetic foot ulcers. Chronic venous leg ulcers are already “wet” due to their highly exudative nature. Whirlpool creates the potential to exacerbate the often macerated condition of the tissue surrounding the wound. In addition, McCulloch and Boyd16 demonstrated that the legs of patients with chronic, venous-insufficiency ulcers immersed in the whirlpool longer than 5 minutes with the leg in the customary dependent position resulted in increased venous hypertension and vascular congestion leading to limb edema.

In the case of the neuropathic foot with or without an ulcer in patients with diabetes, the prolonged exposure to water during whirlpool macerates the skin, leaving the foot more susceptible to injury. Additionally, the warm water contributes to the anhydrotic condition frequently existing with this patient population by washing away the already diminished body oils that assist in protecting the skin.17

Whirlpool therapy may not be available or practical in all healthcare settings because of the equipment required and the need to transport the patient to the area of the facility where the tanks are located.18 Because of infection control issues related to aerosolization, portable tanks taken to patient rooms is a practice that has been eliminated in many settings. Finally, the cost effectiveness of whirlpool is questionable due to its labor intensive nature.

**Pulsatile Lavage with Suction**

Pulsatile lavage with suction (PLWS) has reduced or eliminated the use of whirlpool in many practices. This modality is highly effective in dislodging necrotic tissue and, although technically nonselective, can be of great benefit with judicious placement of the tips dispersing the pulsating irrigant. In addition, this modality has simultaneous suction, which removes the irrigant, exudate, and debris from the wound bed (Plate 17, Page 346).19 This method of debridement is one of the few that can function in tracts, tunnels, and extensive undermining. Pressure settings should be below 15 psi to prevent driving bacteria into underlying soft tissue and to prevent damage to granulation tissue if present in the wound bed.10 Personal protective equipment (PPE) is necessary for the provider. In addition,
treatment should be delivered in an enclosed private treatment area to avoid contamination by aerosolization.\textsuperscript{20} Recently, a flexible polyurethane protective shield to cover the wound area and instrumentation has been developed to assist in preventing or minimizing the aerosolization associated with PLWS. Research has not been done on this protective shield to demonstrate if aerosolization is completely contained when using PLWS. It is essential that the clinician be experienced when treating complex wounds, such as those with fistulas, exposed cavity linings, and ones with long tunnels in body cavities.\textsuperscript{19,21}

**Jet Lavage**

Jet Lavage (Jetox\textsuperscript{TM}, DeRoyal Industries, Powell, Tenn) is a wound-cleansing and debridement modality combining compressed oxygen with a small amount of saline, which delivers a constant stream to the surface of the wound. This modality converts the saline and oxygen into microdroplets, which are then accelerated to supersonic speeds and sprayed on the treatment area gently removing only the necrotic tissue layer, without damaging the viable layer underneath. It has been reported to have a beneficial effect for patients with painful wounds because of a desensitizing effect created by the combination of the spray with air or oxygen.\textsuperscript{22}

The force delivered to the wound surface is dependent upon the rate of the flow of the oxygen. The recommended ranges are from 9 L/min–15 L/min, which delivers the saline at 4 psi–12 psi, respectively.\textsuperscript{22} This is certainly adequate for effective wound cleansing as well as dislodgement and removal of loose surface debris. The latex-free disposable units make this modality useful in all practice settings including home care.

**Wound Irrigation**

Wound irrigation may be used to clean wounds and perform minimal debridement of loose tissue. It is recommended that a 35-mL syringe with a 19-gauge needle or angiocatheter or available pre-packaged systems be used to deliver the optimal pressure to adequately cleanse the wound without harming healthy tissue.\textsuperscript{10} This form of hydrotherapy is ineffective on firmly attached fibrin or slough and eschar due to lack of enough force to dislodge the necrotic tissue from the wound bed.

It is worth mentioning again that due to the aerosolization effects of hydrotherapy modalities, particularly pulsed lavage, jet lavage, and forceful irrigation, the clinician should wear PPE including gloves, fluid proof aprons or gowns, hair covers, masks, and face/eye shields. Upon completion of the procedure, flat surfaces in the room should be wiped down according to the infection-control standards of the facility or agency.

**Wet-to-Dry Dressings**

The dressing technique commonly referred to as either wet-to-dry or wet-to-moist has been documented and most likely remains the most common form of not only debridement but also dressing used in the United States today.\textsuperscript{23} The name carries a bit of irony in that rarely is the gauze dressing placed into the wound bed in a “wet” level of hydration. Rather, the most commonly discussed procedure is to wet open-weave gauze, squeeze or wring it out until it is just moist, and open and place it into the wound bed so that a layer of the gauze is in intimate contact with the wound surface. The proposed mechanism of action is that as the gauze dries and is subsequently removed from the wound bed, it will be adherent to the wound surface and the necrotic tissue will be torn from the wound as the dressing is removed.

This nonselective form of debridement is unquestionably one of the more controversial issues in wound management. The technique carries many disadvantages that overshadow most potential benefits. For example:

1. The procedure is nonselective as a form of debridement and will indiscriminately remove any tissue with which it is in contact
2. Gauze does not have to completely dry to cause trauma to the wound surface—the very absorption of exudate off of the wound surface will cause fibers to become imbedded into the wound tissue and, consequently, adhere on removal\textsuperscript{24}
3. Wet-to-dry dressings often cause pain when removed
4. The gauze is often over packed, causing increased detrimental pressure to the wound, increasing the likelihood of further tissue necrosis
5. Exposed structures, such as bone or tendon,
Wound Debridement

...will likely dry out using this procedure.

Additionally, wet-to-dry dressings may impede wound healing due to local tissue cooling, disruption of angiogenesis by dressing removal, and increased infection risk from frequent dressing changes, strike through, and prolonged inflammation. Wet-to-dry dressings are also labor intensive and costly.

With all of the negatives aside, when performed properly, debridement using this technique can be a relatively quick and often effective method of removing devitalized tissue in a wound bed that is completely covered with necrotic tissue. It is important that adequate, ambient, wound fluid is present to prevent surface desiccation. Additionally, in the presence of massively large wounds, moistened gauze is often the only packing material choice to reasonably, cost-effectively pack into a large defect of space. However, once granulation tissue begins to form in the wound bed, it is imperative that the clinician shift from the wet-to-dry technique to one that will not damage the new, fragile tissue in the wound bed.

Ultrasound

The medical use of ultrasound is not a new concept in medicine. The use of ultrasound to treat many disorders began to appear in the literature as early as 1949. Therapeutic ultrasound delivers energy through mechanical vibrations in the form of sound waves at frequencies above detection by the human ear (> 20 kHz). Historically, ultrasound is commonly associated with diagnostic imaging in which high-frequency ultrasound waves with minimal physiological effects are utilized. In addition, high-frequency therapeutic ultrasound (in the 1 MHz–3 MHz range) has been used in physical therapy, physical medicine, and rehabilitation and sports medicine for many years for treatment of soft-tissue injuries and wounds. Recently, low-frequency ultrasound has been added as an energy to impact tissues in the wound bed.

Ultrasound therapy in general provides therapeutic effects related to the energy created by the sound wave on the tissues at which the energy is directed. The effects are labeled thermal and nonthermal. Thermal effects occur as ultrasound travels through body tissue with a certain percentage being absorbed, resulting in the generation of heat and thermal energy. The degree of absorption depends on the nature of the tissue, the extent of blood flow, and the frequency of the sound wave used. Thermal effects are generally created by high-frequency ultrasound using the 1 MHz–3 MHz range of sound waves creating increased blood flow, reduction in muscle spasm, increased extensibility of collagen fibrils, and a pro-inflammatory response.

Nonthermal effects include cavitation and acoustic streaming and are the primary effects created by low-frequency ultrasound. Cavitation is described as the formation of miniscule gas bubbles in tissue fluids. The expansion and contraction in size of these bubbles occur in tandem with the variations in the ultrasound field-pressure levels. At certain amplitudes of the sound waves, the bubbles implode; this implosion results in the formation of tiny shock waves, the vibration of which causes changes in the permeability of cell membranes. These locally generated shock waves in turn liquefy necrotic tissue, other wound debris, and associated biofilm. Research has shown that such implosion-related shock waves destroy the bacterial cell walls. It has been demonstrated that this process interrupts the metabolism of the bacteria and essentially kills them without damaging host cells.

The second effect of low-frequency ultrasound is acoustic streaming, which initiates a unidirectional movement in fluid in an ultrasound field, causing a temporary disturbance in the cell membrane. This activity causes biochemical effects including an increase in cell membrane permeability, increased protein synthesis, mast cell degranulation, increased growth-factor production, and enhanced nitric-oxide synthetase-mediated cellular mechanisms. All of the aforementioned effects of low-frequency ultrasound ultimately stimulate cell activity and thereby enhance clinical outcomes. There are 2 different types of systems for low-frequency ultrasound: contact and non-contact. Refer to Table 1 for a comparison of these technologies.

Ultrasound-assisted wound therapy (UAW), contact low-frequency ultrasound, has been utilized as a wound debridement and cleansing technique for years in the United Kingdom, Russia, and Germany. This technique of wound de-
bridement has many advantages: the results can be as immediate as sharp or surgical debridement; it generally requires only topical anesthesia, is selective for nonviable or necrotic tissue, and can be effectively used for excisional debridement. Ultrasound-assisted wound therapy is bactericidal at the surface, penetrates into surrounding tissues, and can be performed in a variety of settings by trained personnel. Ultrasound-assisted wound therapy procedures allow therapy at the bedside and can be utilized at the time of surgery to provide adjunctive therapy during incision and drainage procedures.

When using contact low-frequency ultrasound-assisted wound treatment devices, the probe is in intimate contact with the wound bed tissues. These devices currently include Misonix SonicOne™ (Medline Industries, Mundelein, Ill) and Sonoca 180 (Söring Inc, Fort Worth, Tex). The built-in lavage system may provide further reduction of cell debris and bacteria to more effectively cleanse the wound site.

Ultrasound-assisted wound treatment has been proven to eradicate surface and adjacent tissue colonization of bacteria; therefore, individuals with a history of frequent cellulitis caused by multiple resistant bacteria may benefit from the reduced need for systemic antibiotics. Collaborative work done by Pierson and Niezgoda emphasizes the benefits of UAW treatment. Brooke Army Medical Center isolated 25 highly antibiotic-resistant Acinetobacter spp (primarily A. baumannii) from wounded soldiers returning from Iraq. Using a previously described protocol for an in-vitro model, the bacterial suspension was set to a 0.5 McFarland standard and then serially diluted to approximately 100,000 CFU/mL. Initial colony counts were taken prior to sonocacion. Test solutions were treated with sonocacion at 60% output in 10-second bursts, followed by 50-second cool-down periods, until a total of 120 seconds of sonication was achieved. Aliquots were taken and plated after each 20 seconds of sonocacion. Bacterial death was measured by both colony counts after 24 hours of growth and acridine orange staining using a standard protocol. After UAW treatment, a significant log decrease in bacterial load was noted with less than 5% viable bacteria identified after a 120-second treatment.

Contact ultrasonic-assisted wound therapy utilizes low-frequency pulsed ultrasound directed to the wound surface and surrounding tissues via an ultrasound probe. Wound-irrigation fluid is directed through an opening in the probe's tip to administer the fluid directly to the wound surface to serve as a coupling medium, coolant, wound lavage, or flush and topically treat the wound base (Plate 18, Page 346).

Indications for the use of UAW include but are not limited to:

- Locally infected wounds
- Wounds with impaired circulation
- Wounds with the need for debridement, irri-
gigation, and topical treatment
- Pressure ulcers, diabetic foot ulcers, lower-extremitiy diabetic ulcers, and venous ulcers.

Contraindications for the use of UAW include:

- Untreated advancing cellulitis with signs of systemic response
- Wounds with metal components, such as joint replacements, plates, and screws, or implanted electronic devices within the treatment field
- Uncontrolled pain.

The treatment setting for use of UAW therapy is dependent upon availability of the equipment and trained personnel and potentially includes 3 areas. The hospital outpatient clinic is the primary treatment location. With the portability of the equipment, the treatment could also be utilized at the bedside in the acute care and intermediate care setting and in the operating room at the time of surgical incision and drainage, dressing changes, or debridement. The high cost of individual ultrasound units and attachments prohibits providing multiple departments with the equipment.

Noncontact, nonthermal therapeutic ultrasound (MIST Therapy™ System, Celleration®, Eden Prairie, Minn) produces low-intensity (0.1 W/cm²–0.5 W/cm²), low-frequency (40 kHz) ultrasound to promote wound healing through cleansing and maintenance debridement that gradually removes yellow slough, fibrin, tissue exudate, and bacteria. Noncontact, nonthermal therapeutic ultrasound achieves debridement through multiple sessions over an extended period of time. It can be used on a variety of wounds including, but not limited to, acute, traumatic, chronic, and dehisced wounds. Noncontact, nonthermal therapeutic ultrasound delivers
continuous ultrasonic energy via an atomized saline solution to the wound bed without direct contact of the device to the body or the wound. The mist acts as a conduit for transmitting ultrasonic energy to the treatment site. This therapy is also believed to promote wound healing through the processes of cavitation and micro streaming, the effects of which were described earlier in this section. Four clinical studies have evaluated the safety and efficacy of noncontact, low-frequency therapeutic ultrasound in patients with a variety of wounds, including recalcitrant pressure ulcers, chronic lower-extremity leg and foot ulcers, and diabetic foot ulcers. Among these, a randomized, controlled, double-blind trial demonstrated improved healing of recalcitrant diabetic foot ulcers compared with a sham procedure in patients receiving standard wound-care therapy. To use the low-frequency therapeutic ultrasound system, practitioners must remove dressings, discard contaminated materials, and clean the device with the germicidal wipe provided. The applicator is held perpendicular to the wound and moved in slow even strokes vertically across the wound in multiple passes, then repeated in horizontal passes. The recommended distance between the leading edge of the applicator and the wound is approximately 0.5 cm–1.5 cm (0.2 in–0.6 in). Placing an absorbent pad beneath the area of the patient being treated will absorb any saline run-off.

The outcomes of the use of low-frequency ultrasound in wound care may include:
- Wound debridement producing a wound bed with reduced adherent nonviable tissue
- Decreased pain related to the process of decreased bacterial colonization and reversal of the inflammatory state with reduced pH
- Stimulation of granulation tissue formation
- Reduced infection rate
- Reduction of systemic antibiotic use
- Decreased time to closure.

**Autolytic Debridement**

Autolytic debridement is the use of the body’s Table 1. Summary of low-frequency ultrasound technologies

<table>
<thead>
<tr>
<th>Features</th>
<th>Misonix SonicOne™</th>
<th>Sonoca 180™</th>
<th>MIST Therapy™</th>
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<tr>
<td>Frequency</td>
<td>22.5 kHz</td>
<td>20–80 kHz</td>
<td>40 kHz</td>
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<tr>
<td>Intensity</td>
<td>Variable (auto gain control)</td>
<td>Variable 40%–100%</td>
<td>Preset (based on wound size)</td>
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<tr>
<td>Mode</td>
<td>Continuous or pulsed</td>
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<td>Continuous</td>
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<td>Fluid delivery</td>
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<td>Sterile-saline vapor</td>
<td>Sterile-saline mist</td>
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<td>Controls</td>
<td>Foot pedal</td>
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<td>Treatment time</td>
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<td>Usually 2–5 min</td>
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<td>Yes (autoclavable metal probes)</td>
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<td>No (disposable applicator)</td>
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<td>Debridement capability</td>
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<td>Selective</td>
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</table>

Table information adapted. Courtesy of Luther Kloth, PT, MS, FAPTA, CWS, FACCWS.
own available wound fluid to loosen and liquefy necrotic tissue. This fluid contains endogenous proteolytic enzymes, such as collagenase, and inflammatory cells, such as macrophages and neutrophils, which enter the wound site during the normal inflammatory process. In the presence of adequate vascular supply, leukocyte function, and level of neutrophils, the use of moisture-retentive dressings creates an environment providing prolonged contact of this wound fluid with necrotic tissue. This contact softens and ultimately liquefies the devitalized tissue leaving the healthy tissue not only unharmed but also sequestered in an environment conducive to wound healing.

The process of autolytic debridement is slower than other methods, requiring multiple dressing applications, and can often take weeks to accomplish. It is frequently used in combination with other types of debridement, such as pulsatile lavage with suction or instrument debridement. While slower, it is usually a pain-free type of debridement as long as the patient can tolerate the dressings changes. The absence of pain can reduce the stress and anxiety caused by other faster forms of debridement. It also can be accomplished with basic technical skills.

It is important that all members of the healthcare team, the patient, and family members are aware of how the autolytic debridement process is accomplished. Monitoring the fluid collection beneath the selected dressing is essential to prevent prolonged exposure of intact skin, which could lead to moisture-associated skin damage, such as maceration or denudation. Additionally, the collection of fluid containing dead cells, cellular debris, and bacteria, as well as the odor that frequently accompanies this fluid, may lead to the fear that the wound is infected, despite the absence of other clinical indicators. Culture of this material would likely reveal bacteria that are present in the fluid but not pathogenic to the wound, possibly leading to treatment with antibiotics that are not warranted or needed. The wound surface should be thoroughly and safely irrigated or cleansed before an assessment for clinical signs of infection is carried out.

Autolytic debridement can be utilized to debride wounds of all types regardless of etiology. It is frequently the method of choice in the home or long-term care setting where access to other more aggressive forms of debridement may not be feasible or available. The only real contraindication is the infected wound in which faster removal of the devitalized tissue and aggressive drainage and cleansing of the wound surface are critical. See Chapter 5 for further information.

**Enzymatic Debridement**

As described previously, autolytic debridement is a form of enzymatic or chemical debridement, using the body’s naturally occurring enzymes to degrade devitalized tissue. The addition of a topical preparation to specifically target necrotic tissue therapeutically “ramps-up” this process and is generally referred to as chemical or enzymatic debridement. Like autolysis, enzymatic debridement is also an effective alternative to the more expensive and aggressive methods of debridement in settings, such as home or long-term care.

The concept of using proteolytic enzymes to digest necrotic tissue as an adjunct in the treatment of complex wounds is rather old and probably stems from observing the ageless healing techniques of natives in tropical countries. As an example, for wounds, eczema, warts, and ulcers, these natives seem to have utilized the papain-rich material obtained by scratching the skin of the green fruit of the papaw tree (*Carica papaya*). Further, the natives would occasionally expose the wounds to urine and wrap them in green leaves from the same plant. These 3 naturally occurring materials contain the chemical compounds papain, urea, and chlorophyll, which are components of commercial preparations available in certain countries today, papain-urea and papain-urea-chlorophyllin copper.

**Papain-Urea Combinations**

While no longer available in the U.S., papain is used to attack and break down any protein containing cysteine residues, making it rather non-selective because most proteins contain cysteine residues. Collagen contains no cysteine residues and, therefore, is unaffected by papain. The addition of urea facilitates the proteolytic action of papain. Urea alters the 3-dimensional structure of proteins, disrupts their hydrogen bonds, and exposes the activators of papain by solvent action. Urea also contributes to the reduction of disulfide bridges. As the disulfide bridges are reduced,
cysteine residues become exposed, making them more susceptible to the action of papain. Papain and urea combined are probably twice as effective as papain alone. Papain-urea is also active within a broad pH range (3.0–12.0), making it effective for nonspecific bulk debridement. It is also more rapidly effective in breaking down dense necrotic tissue, such as eschar, and devitalized deeper wounds, such as pressure ulcers.

The nonselective nature of this enzymatic preparation is thought to stimulate a prominent inflammatory response, and as a result, there is often pain ranging from mild and transitory to considerable associated with its use. However, in early studies conducted in the 1950s, when chlorophyllin was added to the papain/urea combination, the inflammatory response was reduced considerably. Chlorophyllin derivatives appear to neutralize the breakdown products of the papain/urea combination in addition to reducing malodors. Chlorophyllin–copper complex inhibits the hemagglutinating and inflammatory properties of protein degradation products in the wound, including the products of enzymatic digestion. Its mechanism of action is postulated to be prevention of agglutinated erythrocytes, thus, decreasing thrombus formation, fibrin deposition, and plugging of capillaries and lymphatic vessels.

The effects of chlorophyllin on viable tissue are not clearly understood; however, it is thought that adding this ingredient to the papain/urea combination has no detrimental effect. Published studies and abstracts on the use of papain-urea-chlorophyllin-copper complex have shown that chlorophyllin, in combination with papain/urea, neutralizes inflammatory factors of the enzymatic process. Data suggest that papain-urea-chlorophyllin-copper complex may have a stimulatory effect on granulation tissue and possibly angiogenesis.

An advantage to using the combination of papain/urea may be when the patient requires fast bulk debridement, is not a candidate for surgical/sharp debridement, and/or has deep pressure ulcers with loss of sensation. Disadvantages are the nonselective nature of this debridement process, which may harm healthy tissue and cause inflammation and discomfort to the patient in the absence of chlorophyllin–copper complex.

The recommended use of a papain-urea preparation is a daily or twice daily application depending upon the amount and nature of the necrotic tissue as well as the amount of exudate produced. The ointment is applied directly to the tissue and covered with an appropriate dressing. Cross-hatching of dry or dense eschar or tissue is recommended to facilitate contact and penetration of the ointment and to hasten the debridement process (Plate 19, Page 346). Protection of the surrounding skin with a moisture barrier product can prevent discomfort or denudation of the intact skin from the exudate resulting from the debridement process.

Papain-urea with chlorophyllin copper is generally recommended for use in wounds exhibiting a combination of necrotic and viable tissues to continue the debridement process while protecting and promoting the growth of the healthier viable tissues.

The use of hydrogen peroxide or preparations containing the salts of heavy metals, such as silver, is discouraged with the papain-urea combinations, as these agents may inactivate the activity of the papain.

Collagenase

The only enzymatic debriding agent available in the U.S. at this time is collagenase. Collagenases belong to a family of extracellular MMPs that occur naturally in many tissues and cells in the body. Considering that 70%–80% of the skin consists of collagen, the action of collagenases is important in the cleaning and remodeling of wounds. Collagenases are the only enzymes that can specifically cleave native collagen.

Topical collagenase is a bacterial collagenase derived from Clostridium histolyticum. Reported to be most active in a pH range of 6–8, topical collagenase is specific to native and denatured collagen and is resistant to breakdown by other proteases. This enzyme cleaves collagen (specifically type I and type III) into small peptides, converting it to gelatin, upon which less specific enzymes can then act. Collagenase is thought to promote debridement by digesting collagen bundles that anchor nonviable collagen strands to the wound bed. Until these fibers are severed, debridement cannot take place and granulation tissue formation is slowed, preventing the wound from re-epithelizing. Collagenase
does not break down viable collagen. There are several theories as to why, such as, mucopolysaccharide sheaths, pH gradients within the wound bed, and absence of water. Collagenase has no known effect on viable tissue and is not associated with increased patient discomfort.

The recommended use of collagenase is daily within the area of the wound and more often if the dressing becomes soiled. The ointment is applied directly to the tissue and covered with an appropriate dressing. Cross-hatching of dry or dense eschar or tissue is recommended to facilitate contact and penetration of the ointment and to hasten the debridement process. Protection of the surrounding skin with a moisture-barrier product can prevent discomfort or denudation of the intact skin from the exudate resulting from the debridement process. If a wound infection is suspected, use of Polysporin Powder (bacitracin/ polymyxin B sulfate, Pfizer, New York, NY) on the wound surface prior to application of the collagenase ointment has been studied and found to be effective in reducing bacterial burden.

The use of enzymatic agents for the debridement of necrotic tissue is not new. Pharmaceutical agents for this use have been available since the 1950s. As with autolytic debridement, the only real contraindication is the infected wound in which faster removal of the devitalized tissue and aggressive draining and cleansing of the wound surface are critical (see Chapter 5 for further information). Ongoing use in the healing chronic wound has and is being studied, and the use for maintenance debridement and continued use for prolonged periods of time may be warranted. Necrotic tissue as a clinically visible component of the wound leads clinicians to think of debridement as a single event or single phase in the healing process. While initial debridement is important to remove that particular barrier to healing, maintenance debridement is necessary to keep the ongoing necrotic tissue from accumulating. Apoptosis, or programmed cell death, is a reoccurring process in wounds, resulting in a cycle of adequate blood flow or decreased edema with periods of borderline ischemia and increasing edema. As a result, maintenance debridement becomes necessary, and continued use of less aggressive enzymatic agents, such as collagenase or papain-urea with chlorophyllin copper, may accomplish this and, as a result, promote the proliferation of healthier granulation tissue.

Biotherapy

Biotherapy, also referred to as biosurgery or MDT, is the purposeful use of maggots in wound care.

Historically, maggots have been known for centuries to help heal wounds. Many military surgeons noted that soldiers whose wounds became infested with maggots had a much lower mortality rate and cleaner, faster healing wounds than did soldiers with similar wounds that were not infested. During the late 1920s, William Baer, an orthopedic surgeon at Johns Hopkins University, began to systematically treat, study, and publish case studies of patients with applications of maggots to their wounds. Larval therapy was successfully and routinely performed by thousands of physicians until mid-1940, when its use was supplanted by the new antibiotics and surgical techniques that were developing in World War II. Maggot therapy was occasionally used during the 1970s and 1980s, but only when antibiotics, surgery, and modern wound care failed to control the deteriorating wound. Resurgence in the use of maggots has occurred in the past 10 years, as more widespread acceptance among the medical community as well as patients has occurred.

Maggots have 3 proposed actions: debridement, antimicrobial, and facilitation of wound healing. They are indicated for debriding nonhealing necrotic skin and soft-tissue wounds, including pressure ulcers, venous ulcers, neuropathic foot ulcers, and nonhealing traumatic or post-surgical wounds.

Maggots selectively debride by feeding on the necrotic tissue, cellular debris, and exudate in wounds. The maggot secretes collagenases, trypsin-like, and chymotrypsin-like enzymes, which breakdown the necrotic tissue into a semi-liquid form that the creatures can ingest.

To attach to tissue and provide locomotion, maggots use a pair of mandibles or hooks (Plate 20, Page 347). The maggot also uses these hooks during feeding to disrupt membranes and thus facilitate the penetration of their proteolytic enzymes. Additional debridement may be facilitated by the maggots crawling about within
the wound, dislodging small amounts of necrotic material.

Studies have shown biosurgery using maggots to be an effective and rapid treatment for the debridement of chronic wounds. A Cochrane review of randomized, controlled trials (RCTs) comparing larval therapy to conventional debridement concluded that while “the evidence is insufficient to support a firm conclusion of efficacy of larval therapy in any chronic or acute wound, appropriately powered, prospective RCTs are warranted.” When these RCTs are conducted, it is hoped that maggot therapy will be compared to a hydrogel under a moisture-retentive dressing, a modality with significant evidence of debriding efficacy during 14 days of use.

The ability of maggots to kill or prevent the growth of a range of potentially pathogenic bacteria has been the subject of a number of studies. Marked antimicrobial activity has been detected against *Streptococcus A* and B and *Staphylococcus aureus* with some activity detected against *Pseudomonas* sp and a clinical isolate of a resistant strain of *S aureus* (MRSA).

Growth of granulation tissue has been reported to be faster with better wound-healing rates using maggot therapy. One study suggests a possible mode of action for facilitating wound healing is the increase in tissue oxygenation that takes place when using maggot therapy. Sherman et al demonstrated that maggot therapy enhanced the closure rate of pressure ulcers in spinal cord injury patients.

In 2004, the FDA approved the production and marketing of Medical Maggots (Monarch Labs, Irvine, Calif) as a medical device for the following indications: debriding nonhealing necrotic skin and soft-tissue wounds, including pressure ulcers, venous stasis ulcers, neuropathic foot ulcers, and nonhealing traumatic or post-surgical wounds.

The technique for application and use of MDT is not difficult but is specific. Maggots themselves cannot be disinfected. The eggs are chemically disinfected with Lysol, sodium hypochlorite, or another agent, and then placed in sterile containers so that the newly hatched maggots remain disinfected. The wound bed is cleansed and prepared, and the surrounding skin should be dried thoroughly and protected with a skin-barrier wipe. The wound is “picture-framed” by building 1 or 2 layers of hydrocolloid or pectin skin barrier strips. Commonly, practitioners will apply a skin contact cement (ie, Skin Bond Cement, Smith & Nephew, Largo, Fla). The maggots are applied to the wound with 5 to 8 maggots per cm² of wound surface area, and a closed mesh or veil dressing is applied, adhered to the cemented edged barrier. This prevents “migration” of the maggots outside of the wound area. The wound should be further dressed with gauze or other absorbent materials due to the increased exudate that generally results. The dressing is left in place for 48 to 72 hours, removing the maggots as they become satiated and move to the surface of the dressing. One or 2 cycles are applied each week. The total duration of treatment will depend on the size and character of the wound, the clinical response, and the overall goals of therapy. Instrument debridement of thick, dry eschar or tough fibrous tissue prior to initiation of MDT will hasten the effect and shorten the treatment time (Plates 21–24, Page 347).

**Conclusion**

Regardless of the type or technique used, effective wound debridement is paramount to achieving adequate wound-bed preparation and ultimately wound healing and has become a standard of care among wound care providers. Once the decision to debride is made, the methodology used is dependent upon the patient's plan of care, the overall goals of therapy, the urgency of the need, the setting in which the care is being provided, the skill level of the care providers, and access to the modalities. Adequate wound debridement is essential for successful outcomes in the management of chronic wounds and is critically important to create a wound environment in
which to achieve the desired benefits of modern advanced wound therapies, such as growth factors and bioengineered tissues.

**Self-Assessment Questions**

1. The presence of necrotic tissue in a wound can inhibit healing in the following ways EXCEPT:
   A. Necrosis can mimic or be a source of infection
   B. Necrotic tissue contributes to a prolonged inflammatory response
   C. Necrotic tissue may reduce protein stores
   D. Necrotic tissue can impede migration of healthy cells

2. The most appropriate method of debridement for a patient who is septic or with an infected wound is:
   A. Wet-to-dry dressings
   B. Surgical
   C. Pulsed lavage with suction
   D. Enzymatic

3. Personal protective equipment is required with the following debridement procedure:
   A. Wet-to-dry dressings
   B. Pulsed lavage with suction
   C. Autolytic
   D. Maggot debridement

4. Autolytic debridement liquefies necrotic tissue utilizing naturally occurring:
   A. Red blood cells
   B. Hormones
   C. Leukocytes and enzymes
   D. Growth factors

**Answers:** 1-C, 2-B, 3-B, 4-D

**References**

Wound Debridement


