

Choosing a Wound Dressing Based on Common Wound Characteristics

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Significance: Chronic wounds are a major healthcare burden. The practitioner should have an appropriate understanding of both the etiology of the wound as well as the optimal type of dressings to use. Fundamental wound characteristics may be used to guide the practitioner's choice of dressings. The identification of optimal dressings to use for a particular wound type is an important element in facilitating wound healing.

Recent Advances: Researchers have sought to design wound dressings that aim to optimize each stage in the healing process. In addition, dressings have been designed to target and kill infection-causing bacteria, with the incorporation of antimicrobial agents.

Critical Issues: Chronic wounds are frequently dynamic in presentation, and the numerous wound dressings available make dressing selection challenging for the practitioner. Choosing the correct dressing decreases time to healing, provides cost-effective care, and improves patient quality of life.

Future Directions: Research into the mechanisms of wound healing has enhanced our ability to heal chronic wounds at a faster rate through the use of moisture-retentive dressings. Newer dressings are incorporating the use of nanotechnology by incorporating miniature electrical sensors into the dressing. These dressings are engineered to detect changes in a wound environment and alert the patient or practitioner by altering the color of the dressing or sending a message to a smartphone. Additional investigations are underway that incorporate biologic material such as stem cells into dressings.

SCOPE AND SIGNIFICANCE

THIS REVIEW HIGHLIGHTS the importance of fundamental wound characteristics in selecting appropriate wound dressings. It aims to provide readers with an overview of the different wound types that are commonly encountered as well as the ways in which dressings can optimize the wound bed and promote healing (Table 1).

TRANSLATIONAL RELEVANCE

Acute wounds normally heal in a sequenced and timely manner, characterized by four major phases: coagulation, inflammation, proliferation, and remodeling. Chronic wounds remain stalled in one of these stages (classically, the inflammatory phase) for a multitude of reasons. In addition, uncontrolled matrix metalloproteinases are a major underlying

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Table 1. Recommended dressings for the different wound characteristics

Wound dressing category	Superficial disruptions of skin	Eschar	Exudate	Granulating/epithelializing wounds	Fibrinous wound bed/slough	Deep wounds	Colonized or infected wounds
Films PMDs		Hydrogels Hydrocolloids PMDs	Alginates Hydrofibers Foams PMDs	Hydrocolloids Hydrogels PMDs	Protease lowering dressings Hydrogels hydrocolloids	PMDs Alginates Hydrofiber hydrocolloid	Silver Iodine
Examples	<p>Examples of films:</p> <p>Tegaderm™ (3M Healthcare)</p> <p>Polyskin™ (Kendall Healthcare)</p> <p>Bioclusive® (Johnson & Johnson)</p> <p>Blisterfilm™ (The Kendall Co.)</p> <p>Omniderm® (Omikron Scientific Ltd.)</p> <p>Proclude® (ConvaTec)</p> <p>Mefilm® (Molnlycke Health Care)</p> <p>Carratfilm™ (Carrington Lab)</p> <p>Transeal® (DeRoyal)</p> <p>Example of PMD:</p> <p>Polymem® (Ferris Corp.)</p>	<p>Hydrogels:</p> <p>Vigilon® (CR Bard)</p> <p>Nu-gel® (Johnson & Johnson)</p> <p>Tegagel™ (3M)</p> <p>FlexiGel™ (Smith & Nephew)</p> <p>Clearsite® (Conmed Corp.)</p> <p>Curafil™ (The Kendall Co.)</p> <p>Curasol® (The Kendall Co.)</p> <p>Elasto-Gel™ (SW Technologies)</p> <p>Hypergel® (Scott Health Care)</p> <p>Normgel® (SCA Hygiene Products)</p> <p>2nd Skin® (Spenco Medical, Ltd.)</p> <p>Transigel™ (Smith & Nephew)</p> <p>Examples of Hydrocolloids in another column</p>	<p>Examples of alginates:</p> <p>Algiderm (Bard)</p> <p>Algister™ (Smith & Nephew)</p> <p>Algisorb™ (Calgon-Vestal)</p> <p>Algosteril® (Johnson & Johnson Medical)</p> <p>Kaltostat® (ConvaTec)</p> <p>Curasorb™ (The Kendall Co.)</p> <p>Sortsan® (Dow B. Hickam)</p> <p>Melgisorb® (Molnlycke Health Care)</p> <p>SeaSorb® (Coloplast)</p> <p>Kalginat® (DeRoyal)</p> <p>Examples of foams:</p> <p>Allevyn® (Smith & Nephew United)</p> <p>Biopatch® (Johnson & Johnson Medical)</p> <p>Curafoam™ (The Kendall Co.)</p> <p>Hydrasorb® (Tyco/Kendall Co.)</p> <p>Mepilex® (Molnlycke Health Care)</p> <p>Examples of hydrofibers:</p> <p>Aquace® (ConvaTec)</p> <p>Versiva® XC™ (ConvaTec)</p>	<p>Examples of Hydrocolloids:</p> <p>Duoderm® (ConvaTec)</p> <p>NuDerm® (Johnson & Johnson Medical)</p> <p>Comfeel® (Coloplast Sween, Inc.)</p> <p>Hydrocol® (Dow Hickman)</p> <p>Cutinova® (Smith & Nephew)</p> <p>Replicare® (Smith & Nephew United)</p> <p>Tegasorb™ (3M)</p> <p>Examples of hydrogels and PMDS (see previous columns)</p>	<p>Protease lowering dressings: Promogran</p>	<p>See previous columns</p>	<p>Silver containing dressings:</p> <p>Aquacel Ag® (ConvaTec)</p> <p>Acticoat 7 (Smith and nephew)</p> <p>Actiosorb Silver 220 (Johnson and Johnson)</p> <p>Silversorb (medline)</p> <p>Silvercel (Johnson and Johnson)</p> <p>Examples of Iodine products:</p> <p>Iodosorb gel (cadexomer iodine)</p> <p>Examples of Hydrophobic dressings:</p> <p>Sorbact®</p>

PMDs, polymeric membrane dressings.

cause for the chronicity of nonhealing ulcers. The theory that a moist wound environment is ideal for healing chronic wounds emerged in the 1960s.^{1,2} Many dressings have since been designed to optimize the amount of moisture and promote an ideal wound environment. Choosing the correct wound dressing is an important adjunct to the healing of chronic wounds.³

CLINICAL RELEVANCE

The treatment of chronic wounds is costly both in terms of clinician time and financial resources. The annual cost of caring for chronic wounds in the United States approaches US \$25 billion.⁴ The wound management market is estimated to reach a value of US \$4.4 billion in 2019 from US \$3.1 billion in 2012.⁵ Practitioners can mitigate excessive resource utilization by selecting the optimal wound dressings for patients.

DISCUSSION

Superficial disruptions of skin

In superficial wounds, the damage is generally limited to the epidermis: moisture retentive dressings, either occlusive or semioclusive, help promote reepithelialization. Superficial wounds, including thin burns, catheter sites, partial thickness, and epidermal skin graft harvest sites, often require a basic practical dressing. One option is a film dressing. Films are thin, elastic, transparent polyurethane dressings that provide a barrier to shield from bacterial invasion. They are gas permeable and suitable for delicate and minimally exudative wounds.⁶ Films are not absorptive dressings, and skin surrounding the wound may macerate if fluid is allowed to collect under the film.⁶ Films are therefore not ideal in superficial wounds with more than scant wound exudate. The adhesive backing on films may potentially damage the new epidermis or uninvolved skin that comes in contact with it. Patients with fragile skin, including the elderly or patients with cutaneous atrophy, should decrease the frequency of dressing changes or avoid films altogether.

Hydrocolloid dressings are produced in two forms: a sheet form and a hydrocolloid gel. Both are made of carboxymethylcellulose, gelatin, and pectins. The sheet form has an external semipermeable layer and an internal layer of hydrophilic carboxymethylcellulose molecules suspended in a hydrophobic mass of gelatin and pectins.⁷ Hydrocolloid dressings can be worn for several days before changing, a feature that decreases supply costs, inconvenience, and local trauma associated with dressing changes.⁸ Hydrocolloids can be used

for abrasions, postoperative wounds, smaller and more superficial pressure ulcers, burns, and graft donor sites. Disadvantages of hydrocolloids include the risk of contact dermatitis.^{6,9} Hydrocolloid dressings also produce a malodorous yellow gel on the underside of the dressing referred to as “gel and smell.” Patients should be counseled to expect this as it may be confused with infection.¹⁰ Hydrocolloids are further discussed in the Granulating/Epithelializing Wounds section.

Polymeric membrane dressings (PMDs) are composed of a hydrophilic polyurethane membrane matrix with a continuous semipermeable polyurethane film backing, which come in different thicknesses based on wound exudate. PMDs have been used successfully in donor graft sites and superficial abrasions without overdrying.^{11,12} PMDs contain ingredients that work synergistically to continuously cleanse wounds and expedite healing. Nonadherent PMDs allow for atraumatic dressing changes and may decrease persistent wound pain.¹³ PMDs enhance autolytic debridement, which often results in the production of large quantities of pale yellow enzyme- and nutrient-rich wound fluid during the first treatment week.¹³

Wounds with eschar

Wounds are dry and require the removal of the necrotic tissue: extra moisture should be added to these wounds to optimize healing. Eschar is thick, adherent dead tissue; wounds covered in eschar generally do not produce much exudate (Fig. 1).



Figure 1. An example of eschar overlying a wound bed. This is a patient with polyarteritis nodosa. Notice the thick, adherent fibrinous material. Hydrogel sheet was applied to the wound for 10 days, this softened the eschar. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

Examples of wounds with thick eschar may include ulcers from primary rheumatologic diseases (*e.g.*, scleroderma, discoid lupus erythematosus), coagulopathies (*e.g.*, Coumadin necrosis, vasculitis), or from calciphylaxis.¹⁴ Hydrogel dressings have been shown to be effective in treating eschar. Hydrogels may be selected for patients for whom sharp surgical debridement is contraindicated.^{15,16} Hydrogels are composed of crosslinked hydrophilic polymers designed to bathe the tissue in a water-rich environment and promote autolytic debridement, making use of the body's own enzymes and moisture to rehydrate, soften, and liquefy hard eschar and slough.¹⁶ Hydrogels are available as a sheet or as an amorphous gel (that is then covered by a secondary dressing such as a film, foam, or hydrocolloid). They are composed of 95% water, and patients report that hydrogel dressings are very soothing; however, care must be taken to ensure the dressing changes are frequent enough to avoid macerating the surrounding skin.^{8,17} Another important advantage of hydrogels is that they can be applied and removed with minimal pain or trauma to the wound bed.¹⁸

Another dressing option for wounds with eschar makes use of enzymatic debridement to digest necrotic tissue, using proteolytic enzyme preparations such as collagenase. Enzymatic debriding agents are effective in removing necrotic material from pressure ulcers, leg ulcers, and partial-thickness wounds, especially when alternative methods (*e.g.*, surgical or conservative sharp debridement) are contraindicated. Application of collagenase to the wound bed, followed by a primary dressing to keep the wound moist (examples include hydrocolloids and polymembrane dressings), helps digest necrotic tissue and facilitates a moist wound environment optimal for healing.¹⁹

Exudative wounds

Wounds that produce excess fluid; a dressing that traps the exudate and manages the moisture balance is necessary: dressings are selected based on the relative amount of wound exudate. Wounds with moderate to high exudate may include large venous ulcers and pyoderma gangrenosum. Such wounds benefit from dressings with powerful absorptive capacities that also minimize maceration of surrounding healthy skin (Fig. 2). It is important to keep in mind that once dressings and compression are applied to the wound, more exudate is subsequently produced. Asking the patient how many dressing changes they perform each day provides the clinician with a relative estimate of the amount of wound exudate. One to two dressing changes per day is considered mild to mild-



Figure 2. Example of a wound with moderate amount of exudate, this is a traumatic injury that resulted in an ulceration. A hydrofiber dressing was applied to the wound to absorb the exudate. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

moderate; two to three dressing changes a day is considered moderate; and more than three dressing changes is considered heavy exudate. Four classes of dressings have been designed to absorb large amounts of exudate, while preserving an appropriate amount of moisture that is necessary for wound healing: alginates, hydrofibers, foams, and PMDs.

Calcium alginate dressings are derived from algae or kelp polysaccharides. Once in contact with a moist wound, an ion exchange reaction occurs between the calcium in the alginate and the sodium in the exudate, producing a soluble calcium-sodium alginate that forms a gel. This gel in turn helps maintain a moist wound environment.¹⁰ Alginate dressings can absorb up to 20 times their weight in wound fluid, which makes them effective for wounds with moderate to heavy exudate. They may remain in place for several days, thus requiring less frequent dressing changes.^{20–24} Another advantage of alginate dressings is their inherent ability to augment hemostasis, as release of calcium ions leads to platelet activation.^{25,26} Calcium alginate dressings may be painful to remove if used on wounds with only small amounts of exudate. Additionally, alginates frequently require a secondary dressing, which increases the cost per dressing change. Another disadvantage of alginates is their tendency to allow wound fluid to collect between the dressing and intact periwound skin; this so-called “lateral wicking” leads to undesirable maceration of surrounding intact skin.²⁷

Hydrofiber dressings are not derived from algae or kelp but have similar absorptive properties as

alginates. Hydrofibers are made of carboxymethylcellulose fibers, which interact with wound exudate to form a gel and can be up to three times as absorbent alginates.²⁸ Hydrofibers are employed in a similar manner as alginates: these dressings are effective for wounds with moderate to excessive (heavy) exudate and can be left in place until the dressing is saturated. Relative to alginate dressings, hydrofiber dressings demonstrate less lateral wicking and subsequently less maceration of intact periwound skin.¹⁰

Both alginate and hydrofiber dressings can produce a fibrinous residue that is visible on the wound bed surface at dressing changes; this should be gently rinsed away. Both dressings can be used in mildly exudative wounds but may need to be soaked in sterile water or saline before removal to reduce associated pain and minimize trauma to the wound bed.

Foam dressings are another type of moisture-retentive dressing designed to accommodate fluid while adding bulk and cushion to the wound bed. These are generally thicker dressings that have a bilaminate structure with a hydrophilic surface. Because of this hydrophilic component, foams may be too drying on wounds of minimal or mild exudate and may necessitate a saline soak before dressing change to minimize pain and trauma. Foams are not recommended for heavily exudative wounds. They are frequently nonadherent and necessitate a secondary dressing as a bolster to prevent shifting. Foams are particularly well suited for wounds over a bony prominence. They require more frequent dressing changes compared to alginates and hydrofibers and accommodate relatively less wound fluid than these dressings. In addition, foam dressings may be associated with a malodorous discharge similar to the gel and smell observed in hydrocolloids.

PMDs have a semipermeable polyurethane film backing and are available in various thicknesses and sizes; more exudative wounds are best suited by a thicker dressing.¹¹ PMDs are not drying on wounds with mild exudate; the dressing can be soaked in sterile water or saline to further moisten the dressing and prevent overdrying of the wound bed.¹¹

Lateral wicking causing periwound skin maceration can be hard to distinguish from a contact dermatitis secondary to wound dressings. Patients with chronic leg ulcers often develop allergic contact dermatitis secondary to topical medications or wound dressings. Although relatively few studies are available on this topic, hydrogel, hydrocolloid, and silver dressings have been associated with

contact sensitization.^{29,30} To date, there are no reports of contact sensitization from alginate or foam dressings, with the exception of adherent foams^{29,30}

Granulating/epithelializing wounds

Wounds primarily demonstrate erythematous granulation tissue at the base without excessive exudate or overlying debris: dressings should promote granulation tissue formation to allow for epithelialization without overgranulating the wound. Granulation tissue begins to appear in a wound space ~4 days after initial injury. Macrophages, fibroblasts, and blood vessels invade the wound space at the same time. Numerous new capillaries grow within the wound stroma, lending it the classic granular appearance.³¹ On examination, granulation tissue typically appears deep pink or red with an irregular berry-like surface.³ A fully granulated wound is defined as follows: a wound bed filled with granulation tissue to the level of the surrounding skin or new epithelium; no dead space; no avascular tissue; no signs or symptoms of infection; and with open wound edges (Fig. 3A). Early or partially granulated wounds are defined as follows: >25% of the wound bed filled with granulation tissue; minimal avascular tissue; possible dead space; no signs or symptoms of infection; and with open wound edges.^{3,32} A number of dressing types can be appropriate in all stages of granulating wounds; the amount of wound exudate may ultimately guide the practitioner's choice of dressing.

Wounds that are completely granulated and in the process of epithelializing benefit from a dressing that will not disrupt the new epithelial growth. Clinicians can determine if a wound has epithelialized by performing the wrinkle test.³ A cotton tip is gently applied over the wound bed; if the clinician observes wrinkling, this implies that epithelial cells have successfully migrated over the wound bed.³ Even wounds that have reached the epithelialization stage can still remain exudative, and care should be taken in selecting a dressing that does not dry out the wound bed. Gentle irrigation with sterile saline prior to dressing changes may be helpful to ensure nontraumatic removal.

In granulated wounds with a mild to moderate exudate, a hydrocolloid dressing is a good choice as it maintains the granulation tissue and aids in epithelialization (Fig. 3B). In the presence of wound exudate, the hydrocolloid dressing absorbs liquid, forms a soft gel, and deters leakage.⁶ Initially, the dressing is impermeable to water vapor. As the gelling process continues, the dressing becomes progressively more permeable, thereby absorbing more exudate. This lowers the wound bed

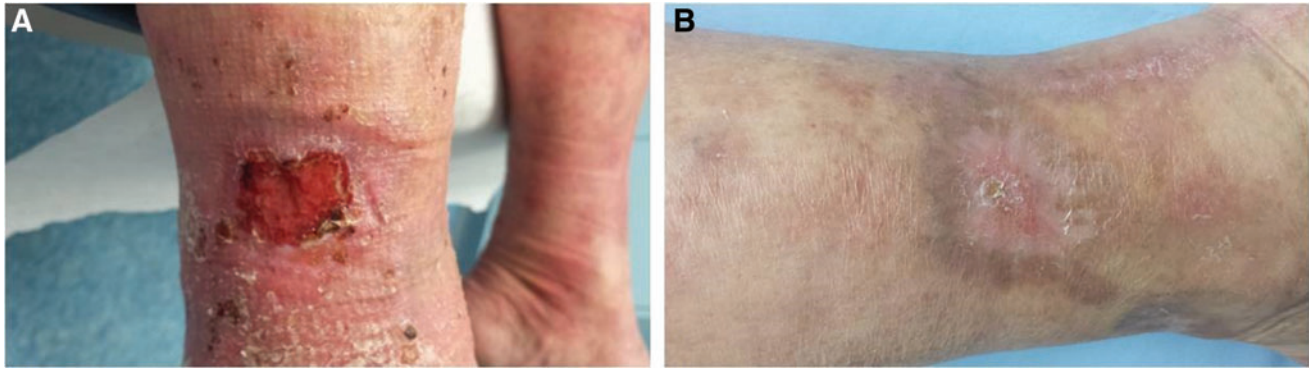


Figure 3. An example of a fully granulated wound bed. **(A)** This is a venous ulcer on the right lateral malleoli. Notice minimal exudate and 100% granulation tissue evident on the wound bed. A hydrocolloid was applied to the wound. Over the primary dressing, the patient wore compression stockings. **(B)** After 4 weeks the wound had healed. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

pH, thus preventing bacterial growth and optimizing wound temperature and moisture level. These conditions allow for proliferation, angiogenesis, and epithelialization.⁷

Foams are an appropriate choice for wounds with a moderate amount of exudate provided it does not stick to the wound bed and disrupt epithelialization. As described previously, alginates form a hydrophilic gel when the dressing comes in contact with wound exudate, and this gel preserves moisture in the wound bed and facilitates granulation and epithelialization.²² Polymer membrane dressings contain glycerol in the dressing, which prevents the dressing from sticking to wounds and facilitates reepithelialization.

Dressings that promote granulation tissue formation confer a risk of overgranulation. Overgranulation of wounds may also be due to the underlying wound infection or malignancy. Clinicians should investigate the etiology of persistent, excessive granulation tissue with histologic examination and wound culture, and treat as necessary. In the absence of infection or malignancy, we find that applying external pressure to the wound bed with nonstick gauze and a secondary compression wrap is helpful to suppress overgranulation. A mid-to high-potency topical corticosteroid such as triamcinolone 0.1% ointment or clobetasol 0.05% ointment applied twice daily to the wound bed reduces granulation tissue production. This must be weighed against the increased risk of local infection. Gentle cautery with silver nitrate sticks can be helpful for excessive granulation tissue of a limited surface area.

Fibrinous wound beds (slough)

Wounds admixed with devitalized tissue will not fully granulate and epithelialize: removal of slough is

achieved by specialized dressings and various methods of debridement. Fibrin, commonly referred to as slough, is firmly adherent, tan to yellow-colored avascular tissue, which may be dry or slightly moist. This is not necrotic tissue, but rather a complex mixture of fibrins, degraded extracellular matrix proteins, exudates, white blood cells, and bacteria.³ Fibrin may be mixed with granulation tissue (Fig. 4A). Slough impedes granulation tissue formation and ultimately epithelialization, so a dressing is selected that will aid in slough removal. There are multiple ways in which to do so, and debridement is perhaps the most effective. Types of debridement include mechanical, which employs a wet-to-dry dressing, usually with normal saline; surgical, with a sharp scalpel or curette; enzymatic; and autolytic. There are dressings specifically designed to promote autolytic debridement, which include thin films, honey, alginates, hydrocolloids, and PMDs.⁶⁻⁸ Hydrogels and hydrocolloids are additional dressing choices that may be effective in removing slough.^{6,8}

Bacterial endotoxin, platelet degranulation products, repeated trauma, tissue degradation, and postischemic reperfusion all promote stimulation of cytokine inflammatory mediators, leading to elevated levels of proteases and a shift in the wound equilibrium toward destructive processes. This increase in the proteolytic activity is thought to contribute to impaired healing.^{3,33} Studies have shown that chronic wound fluid contains elevated protease levels known to have deleterious effects, such as the degradation of *de novo* granulation tissue and endogenous biologically active proteins such as growth factors and cytokines.^{34,35} Protease-lowering dressings have demonstrated efficacy at removing slough, promoting granulation tissue formation, and stimulating wound repair.³³



Figure 4. An example of a partially granulated wound with fibrin adherent to the wound bed. **(A)** This is a venous ulcer on the patient's right medial malleoli. There is mild to moderate exudate. Granulation tissue is visualized within the fibrinous wound bed. Bedside debridement was performed. Patient was prescribed a collagenase. The collagenase was applied daily to the wound bed with a foam dressing. **(B)** After 3 weeks the wound had 100% granulated. A hydrocolloid was applied to the wound. Over the primary dressing, the patient wore compression stockings. **(C)** By week 6 the wound had healed. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

An example of a protease-lowering dressing is the phosphorylated cotton wound dressings prepared to target sequestration of proteases from chronic wound exudate through a cationic uptake binding mechanism involving salt bridge formation of the positively charged amino acid side chains of proteases with the phosphate counter-ions of the wound dressing fiber.³⁶

Enzymatic debridement is achieved by using proteolytic enzyme preparations, such as collagenase, to digest slough. Enzymatic debridement agents are an effective alternative for the removal of nonvital tissue from chronic wounds, especially when surgical or conservative sharp wound debridement are not possible (*e.g.*, in a patient with a bleeding disorder or high risk of infection). Our clinical experience suggests that initial conservative sharp debridement at the bedside followed by serial enzymatic debridement with collagenase is effective at managing slough for many patients with chronic wounds (Fig. 4B, C).

Deep or tunneling wounds

Dressings need to fill the wound cavity effectively to absorb exudate. Deep wounds, like those seen with pyoderma gangrenosum, arterial ulcers, diabetic ulcers, pressure ulcers, abscess sites, surgical sites, or radiation burn sites, may extend to the subcutis or beyond and may exhibit undermining of wound edges. When a wound is deep or tunnels under the skin, packing the wound can expedite healing. Without packing, a wound may close superficially before healing the deeper areas of the defect.³ The purpose of the packing material is to absorb drainage, cleanse, fill, and moisten wound cavities to promote healing from the inside out. PMDs have been shown to be effective in the

healing of deep wounds as they are able to perform these roles.^{13,37} Other dressings that have traditionally been used to treat deep dermal wounds include alginates, hydrofibers, and hydrogels.^{3,6,8}

Infected or colonized wounds

Dressings should aim to decrease the microbial burden without causing cytotoxic effects. The presence of bacteria in a wound may result in

- Contamination—the bacteria do not increase in number or cause clinical disease
- Colonization—the bacteria multiply, but wound tissue is not overtly damaged
- Infection—the bacteria multiply, healing is disrupted, and wound tissues are damaged (local infection). Nearby tissues may become involved (spreading infection) or systemic illness may result (systemic infection).³⁸

Infected wounds clinically present with increased erythema, edema, warmth, and pain; a purulent exudate or increase in wound drainage; and new or worsened malodor (Fig. 5A). Systemic signs such as fever, chills, and leukocytosis are indicators of progression to bacteremia or septicemia.⁸ In such cases, systemic antibiotics are warranted. Infected wounds should be cultured and sensitivities used to tailor antibiotic choice. Superficial swab cultures are of limited value because wounds, like skin, are covered with transient bacteria. Quantitative swab techniques are recommended to determine which microbes have actually invaded the tissue.³⁹ Recently, a point-of-care biosensor has been designed to detect the presence of bacteria or certain proteins and enzymes that are indicators of wound infection. Practitioners only need to drop a small amount of

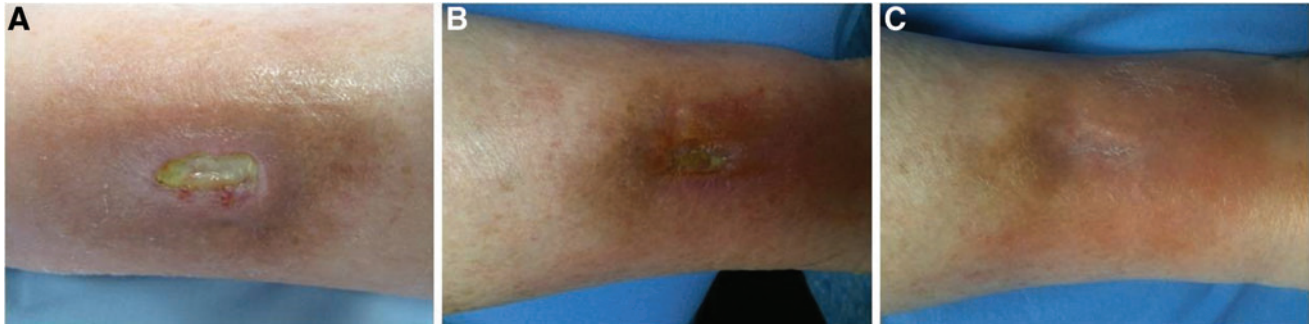


Figure 5. An example of a highly colonized wound. **(A)** This is a highly colonized wound. There is excessive purulent exudate without the signs of infections (red, warm, tender). A wound culture was obtained, which grew back normal skin flora. Bedside debridement with a curette was performed. The silver dressing was held in place with telfa dressing; over both dressings the patient wore tubular elastic compression stockings. **(B)** Six weeks later, the wound partially healed and the film of colonization was well controlled, the same dressings were continued. **(C)** By week 8 the wound had healed. To see this illustration in color, the reader is referred to the web version of this article at www.liebertpub.com/wound

wound fluid onto the sensor, and results are available in minutes. The test can be administered each time a dressing is changed. In addition, researchers are developing smart dressings to automatically release a treatment in response to changes in the wound microenvironment; releasing an antibiotic, for example, if the temperature of the wound reaches a certain level.⁴⁰

In chronic wounds, bacteria may impede wound healing without obvious clinical signs of infection (critically colonized).³⁸ Topical antiseptics frequently used to cleanse wounds include hydrogen peroxide, Dakins solution (bleach and water), eusol solution (bleach, boric acid, and water), and acetic acid (one tablespoon white vinegar in a cup of water). These solutions cannot be used for a prolonged period of time due to their ability to cause tissue injury (each dressing change for no more than 10 min).⁴¹ Most guidelines recommend against the use of antiseptics except in special situations, such as a single dilute vinegar wash for recalcitrant *Pseudomonas* species.⁴²

Topical antibiotics are useful when the sensitivity of the organism is known. Mupirocin is effective against gram-positive organisms, including methicillin-resistant *Staphylococcus aureus*. Topical metronidazole provides good anaerobic coverage.⁴³ These agents are applied directly to the wound bed with an appropriate dressing and then placed over the topical preparation.

Antimicrobial dressings include iodine-based preparations as well as silver-releasing agents and have been formulated to be noncytotoxic. Cadexomer iodine is bactericidal to all gram-positive and gram-negative bacteria as well as fungi, and it facilitates a moist wound environment.⁴⁴ Cadexomer is a starch-based polymer bead that promotes the absorption of fluid, exudate, debris, and bacteria,

while facilitating the controlled release of iodine at levels that are not toxic to human skin cells. Cadexomer iodine is less cytotoxic than other iodine products locally at the wound site, however, it may be absorbed systemically and can be fatal to susceptible individuals (concomitant thyroid disease).⁴⁰ A recent meta-analysis reported that cadexomer iodine dressings may be associated with improved healing compared to standard of care.⁴⁵

Silver ions bind and disrupt bacterial cell walls, which damage intracellular and nuclear membranes, thereby denaturing bacterial DNA and RNA.⁴⁶ Silver has been incorporated into many dressings. An international group of experts in wound care compiled a consensus guideline on the appropriate use of silver dressings. This consensus document recommends silver dressings be used in the context of accepted standard wound care for infected wounds or wounds that are at high risk of infection or reinfection. It is recommended that silver dressings be used for an initial 2-week challenge period, after which the wound, patient, and management approach should be re-evaluated to determine if a silver dressing remains appropriate or if a more aggressive intervention is indicated.⁴⁷ Silver has been shown to be effective as an antimicrobial agent (Fig. 5B, C). It is important to note that silver ions—not silver atoms—produce the antimicrobial affect. Therefore, silver dressings require moist wound environments to release their active agent.^{8,46} Newer silver dressings aim to decrease the cytotoxicity seen in older silver dressings. PMDs with silver are one such example.

The antibacterial activity of silver nanoparticles against certain drug-resistant bacteria has been established. Silver nanoparticles are effective broad-spectrum biocides against a variety of drug-resistant bacteria, which makes them a desirable

candidate for use in pharmaceutical products and medical devices designed to prevent the transmission of drug-resistant pathogens in different clinical environments.

A hydrophobic antimicrobial dressing is a newer type of dressing that has been created. This dressing claims to reduce the bioburden in wounds without using any chemically active agents. Instead, a physical principle is used to bind bacteria and fungi to the dressing in the presence of moisture. It is based on the knowledge that two hydrophobic particles bind together in the presence of moisture. Bacteria are hydrophobic and, therefore, bind to the hydrophobic dressing. When the dressing is changed, the bacteria are removed. The natural binding and removal of microorganisms imply that the release of bacterial endotoxins in the wound is prevented.⁴⁸

SUMMARY

Millions of patients suffer from chronic wounds in the United States. Treating nonhealing wounds is costly, both in terms of practitioner time and physical resources required.⁴ A complex series of events must take place for a wound to fully heal. Chronic wounds are arrested in a state of inflammation, and many devices and dressing types have been designed to subdue the inflammatory response allowing wounds to ultimately heal. Choosing a proper dressing is one important aspect of healing chronic wounds.

The evidence for the use of moisture-retentive dressings is growing. Selection of these dressings is best guided by the wound characteristics in relation to the dressing characteristics: superficial wounds (films, hydrocolloids, PMD); wounds with eschar (hydrogels, hydrocolloids, PMD); exudative wounds (calcium alginates, hydrofibers, foams, PMD); granulating wounds (hydrocolloids, foams, PMD); wounds with slough (protease-lowering dressings, hydrogels, hydrocolloids); deep or tunneling wounds (alginates, hydrofibers, hydrogels); and infected or colonized wounds (silver and iodide). Polymer membrane dressings are revolutionizing the way dressings are made, as these dressings can be used on any type of wound. Recent advances in dressings have incorporated nanotechnology that allows clinicians to utilize the dressing's data to tailor wound management. One hopes that in the next few years these smart dressings will become more widely available for

TAKE-HOME MESSAGES

- Wound dressing selection should be tailored based on fundamental wound characteristics.
- Patients can develop complications from wound dressings (e.g., contact allergic reactions, maceration of healthy skin).
- Frequent inspection of the wound is necessary to optimize wound dressing selection.
- Future dressings aim to provide the practitioner with quantitative data that reflects the changing wound environment.

use. Practitioners should bear in mind that many patients perform dressing changes independently, and at home, so a dressing must be selected that patients can properly apply, is comfortable, effective at balancing moisture, and promotes cost-effective care.

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Abbreviation and Acronym

PMDs = polymeric membrane dressings