Hydroconductive Wound Dressings

Here's a discussion of the mechanism of action and wound care optimization.

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The ideal wound dressing has a number of well-established characteristics which include: 1) the maintenance of a moist wound environment; 2) facilitation of the autolytic debridement process; 3) providing a barrier to bacterial invasion and controlling the growth of bacteria on the wound surface; 4) protecting the wound from physical trauma to help reduce pain at the wound site during application and removal and during the day; 5) be adaptable to the size and shape of the wound; and 6) control of fluid production or need for moisture at the wound surface.

Foster, et al. added the additional characteristics of 1) having minimal bulk; 2) ability to be enclosed in a shoe or off-loading device; 3) being able to withstand shear forces, 4) being resistant to bacterial colonization; 5) being highly absorptive; and 6) being easy to change as particular characteristics for dressings used to treat the diabetic foot wound.

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Wound Classification

Wound dressings can be classified based on their ingredients or their function, but in many cases a practical classification is simply based on their ability to manage fluid. Dressings can add fluid such as in hydrogels, maintain the fluid produced by the wound such as in films and hydrocolloids, or remove and collect fluids such as in alginates, foams, or composite dressings. Recently, a number of new dressings have been produced that are capable of absorbing and/or collecting large volumes of fluid in an attempt to maintain a healthy moist wound surface yet prevent maceration from excess fluid production.

Many wounds produce high volumes of fluid during a 24-hour period. Venous leg ulcers, colonized or infected wounds, and diabetic neuropathic wounds drain constantly during the day and often saturate dressings, resulting in the proliferation of bacteria and the accumulation of fluid.

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New Concepts and Studies

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necrotic debris on the wound surface. Cells don’t live long in a desert or in the middle of a sea of drainage. It is the job of the clinician to determine the proper dressing to maintain a healthy moist environment that allows the wound to heal.

Hydroconductive Wound Dressings

Hydroconductive wound dressings (HCWDs) are more recent additions to a long list of fluid-management dressings, and at the present time are only available from one company. By virtue of their fluid management technology, they have proven to be effective in the treatment of a variety of wound types where fluid control is a key component. HCWDs depend on the capabilities of the fiber utilized in the construction of the dressing. There are three mechanisms that are believed to govern the action of HCWDs: capillary action, hydroconductive action, and electrostatic action.  

Capillary Action

Capillary action (Figure 1) is defined by dictionary.com as "a manifestation of surface tension by which the portion of the surface of a liquid coming in contact with a solid is elevated or depressed, depending on the adhesive or cohesive properties of the liquid." This determines the ability of a liquid to flow in narrow spaces without the assistance of and in opposition to external forces like gravity. The temporary hydrogen bonds formed by liquid molecules, principally water, account for the surface tension we see and the attraction of a fluid to the walls of a small tube.

Transpiration or evaporation from the outer or exposed surface of the tube, or in this case the dressing, allows for a constant movement of fluid up along the sides of the capillaries to the top where it can be removed by evaporation. This principle is applied in HCWDs. The pores in the dressing act as a conduit for wound fluids, and by capillary action direct wound exudate to the external surface of the wound dressing and away from the wound bed. This allows for the removal of cytokines and harmful metalloproteases which are produced in high numbers by the cells in the chronic wound. Rapid removal of inflammatory exudate and resident bacteria decreases the ability of biofilms to form and reduces the possibility that the wound bed will develop a hyper-inflammatory state.

The constant removal from the wound bed of as much as 150 ccs per hour prevents the buildup of pro-inflammatory cytokines such as interleukin 1,6,8, tumor necrosis factor, gamma interferon, and proteolytic enzymes such as matrix metalloproteases (MMP) 2,6,7 by stagnation of wound fluid on the wound surface. Similar to negative pressure devices, the constant removal of fluid from the wound allows for a reduction of wound bed and peri-wound edema, which facilitates better perfusion of the wound and prevents capillary ischemia from excessive peri-wound edema. In addition, fluid flow facilitated by the HCWDs acts to enhance the normal autolytic debridement process, loosening slough and fibrin from the

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wound bed and making their removal easier (Figures 4 a,b).

**Hydroconductive Action**

Darcy's Law is an equation that describes the flow of a fluid through a porous medium and is the basis for the hydroconductive property of HCWDs. Darcy's Law explains the movement of water in both vertical and horizontal directions in a porous medium such as a dressing. The hydroconductive action of these dressings uses this principle to achieve their unique ability to not only move fluid by capillary action, but also by the rapid movement of fluid up into and throughout the dressing (Figure 2).

The HCWD is able to conduct and transfer fluids in both vertical and horizontal directions and allow for transpirational evaporation from the outer surface of the dressing, the mechanism that governs evaporation of water from plants' leaves. Transpiration off the dressing surface allows for high volumes of fluid to be removed from the wound bed and prevents maceration of the wound bed and margins, preventing periwound irritation and even expansion of the ulceration. This was demonstrated in a study by Smith, et al. that was conducted on partial-

**Electrostatic Action**

The third and final mechanism by which HCWDs draw bacteria and deleterious cytokines and proteases from the wound is by electrostatic action (Figure 3). This principle is based on the electrostatic attraction between bacteria and the dressing.

According to the manufacturer, HCWDs have been found to be slightly negatively charged, which one would expect would repel the generally negatively charged bacteria and wound cytokines. However, studies have shown that when the dressing surface comes in contact with ions from fluids of an opposite charge, it binds to the dressing, effectively producing an electric double layer that results in the surface having a net positive charge, thereby attracting the negatively charged bacteria and cytokines.

The strong capillary and hydroconductive forces draw fluid-containing bacteria and cytokines vertically and horizontally into the dressing where they become attracted to and trapped by the fibers.

Removing the bacterial burden from a wound bed and reducing the volume of deleterious cytokines helps in creating an optimal environment for wound-healing.

Although wound exudate isn't well understood in the pathophysiology of a chronic wound, there is a consensus that the accumulation of wound exudate in the wound bed acts as impedance of optimal wound care. Wound exudate is fluid-rich in protein and other nutrients that ooze out of capillaries due to inflammation. Clinicians can attempt to control or reduce the production of wound exudate by debridement of necrotic debris from the wound, or by application of oral or topical antibiotics and antiseptics to the wound bed. They can reduce edema by compression and control inflammation by the use of anti-inflammatory medications.

Despite our attempts at control, often the negatives outweigh the positives, and wound chronicity develops. Local management of wound exudate is an additional tool for preparing and maintaining wound healing. Oral and topical antibiotics and antiseptics carry both systemic and local complications that include local and systemic toxicity and allergic reactions. Repetitive application of antibiotics and some antiseptics not only have the risk of the development of biofilm production and resistance in the bacteria, but also cause significant local inflammation when the bacte-
ria are destroyed on the wound surface. Physical removal of bacteria and cytokines from the wound surface using an HCWD eliminates the concerns in both areas.

**Biofilm Development**

Biofilm development begins when free-floating planktonic bacteria attach to a surface and begin rapid cell division in response to intracellular communication referred to as quorum sensing. Bacteria coat themselves with an extracellular polymeric substance or EPS. EPS is used as a shield against white blood cells, antiseptics, and antibiotics. However, the biofilm requires a stable attachment in order to successfully infect the host. It achieves this by producing host cell senescence and increasing the local pro-inflammatory environment.

In this inflammatory environment, transudate leaks from the local vascular bed, providing an abundant source of nutrient for the biofilm. Dressings such as HCWDs act to reduce both planktonic bacteria and the inflammatory cytokines and transudate used by them as substrate for their growth. The prudent clinician should make every effort to control wound exudate to avoid such complications.

**Case Study**

A 67 year old, poorly controlled Type II diabetic female was referred from the Temple hospital ER for a painful venous ulceration in the area of the medial malleolus, which had healed and recurred several times in the past. The patient had a history of multiple ulcerations and a past medical history that included hypertension, deep vein thrombophlebitis, and hypercholesterolemia. Her blood glucose level that morning was 159 mg/dl and she had a BMI of 34.942. Her DP and PT pulses were 1/4, with evidence of venous stasis and hemosiderosis of both lower extremities with the right being greater than the left.

The patient was also neuropathic...
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with a loss of protective, vibratory and light touch sensations bilaterally. Her wound was located over the right medial malleolus and measured 5.5cm L x 3.0cm W, and 0.3 cm. D. She was classified as a CEAP 6 and a Wagner Wound Grade II. The wound bed was 80% red, 20% yellow slough with several areas that had a black tint suggestive of a pseudomonas biofilm. The exudate level was high, and the wound margins were macerated. There was a moderate wound odor, and the

Conclusion
With over 3,000 wound care products in over 50 categories on the market today, the clinician has a responsibility to make every attempt to use evidence-based wound dressings and to customize treatments to the presenting characteristics of a patient’s wound. HCWDs have the ability to remove large volumes of fluid from the wound, while at the same time facilitating autolytic debridement and improving wound

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outcomes. HCWDs have been shown to decrease wound exudate and tissue bacterial levels, interfere with biofilm production, reduce deleterious cytokine levels, and both facilitate and maintain wound bed preparation in a number of wound types. Hydroconductive dressings give the clinician the ability to achieve optimal wound healing in less time with virtually zero dressing-related complications.14 PM

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