CHAPTER 12

WOUND CARE CONCEPTS, PRINCIPLES, AND PRODUCTS

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Over the past twenty years, the field of wound care has received almost as much attention as any other field in medicine. You cannot pick up a medical journal or magazine today without an article or reference to wound care or wound care products. The incredible volume of wound care products available makes it almost impossible for the practitioner to keep up with all of them. The Wound Care Products Resource lists several hundred wound care products carried by as many companies.[1] Most of the dressings fall into five main classes, and a general knowledge of these classes and their indications and contraindications can equip the practitioner with the ability to choose an appropriate treatment plan, or change that plan as a wound heals or fails to progress. Appropriate wound care will not only reduce treatment time but cost as well. In today's medical environment, the "bottom line" often dictates what health care plans will allow.

The purpose of this paper is not to pass judgment on particular products or treatment modalities, but to educate or reacquaint the reader with the indications, contraindications, and benefit claims of these products and modalities. A general working knowledge of these products and principles, will allow the practitioner to develop a strategy on the treatment of different wounds as they present. A basic review of the principles and phases of wound healing and patient assessment will be presented followed by a discussion on different treatment modalities and products such as Hyperbaric Oxygen, Procuren and growth hormones, as well as the different classes of dressings and wound care products.

PRINCIPLES AND PHASES OF WOUND HEALING

Wound healing can be divided into three phases, inflammation (exudative or substrate), proliferation (fibroblastic), and remodeling (maturation). Each phase has a characteristic sequence of events and length of time. When a patient presents with a chronic non-healing wound, the process of healing has been arrested in one of these phases by either intrinsic factors, extrinsic factors, or both.[1] Identifying these factors is essential to attain wound healing and will be discussed in the following section on patient assessment.

The inflammatory phase begins immediately after an insult to tissue, and can last anywhere from 1 to 5 days. This phase is marked by an array of intense physiologic activity which starts with an initial vasoconstriction which may last 5 to 10 minutes. This is followed by dilation of vessels which result in the leaking of blood elements into the wound site. It is at this time that the wound healing cascade begins. Exposed collagen binds with platelets and activates coagulation and platelet aggregation factors. Chemotactic factors are also released from the platelets and start the inflammatory response. The first primary cells are Polymorphonuclear granulocytes (PMNs). The extent of their presence is dictated by the presence of infection and/or debris. Macrophages are the second cell to arrive. They function to debride injured tissue and secrete chemotactic factors which in turn recruit more macrophages and stimulate fibroblast formation. They also breakdown macromolecules into amino acids and sugars, and secrete lactate, which is a cofactor in the synthesis of collagen.[1-3]

The proliferative phase usually begins about day 5, and can last until week three. It begins after debris and necrotic tissue have been removed and the wound is decontaminated. It is during this phase that fibroblasts proliferate and produce collagen. It is also during this phase that the effect of the release of growth factors is seen by the stimulation of fibroblasts, capillary endothelial cell mitosis, and epidermal cell mitosis. Epithelization marks the end of the proliferative phase as it is seen with the migration of epithelial cells from the wound margins to the wound bed.

The remodeling phase starts at about the third week and lasts months to years. It is during this

phase that unorganized collagen is rewoven into an organized tight pattern providing maximum tensile strength of the wound. A balance is seen with collagen deposition and lysis and a finer, softer scar is produced.

In order for this intricate phasic process to progress satisfactorily, an optimal environment must be maintained. Essential constituents of this environment include moisture, adequate oxygen tension, vascularity, and temperature. A moist environment is paramount for optimal angiogenesis and cell migration.[4] In spite of clinical and laboratory studies, many physicians continue to use wet to dry dressings which can dry up a wound bed and cause the removal of newly developed granulation tissue with removal of the dressing. Adequate vascularity provides the wound with essential nutrients, oxygen, and blood cells essential in the wound healing process, while the optimal temperature is near normal body temperature. All of these constituents are overlapping, and an absence or abnormality of one will impede the whole wound healing process. In order to determine if all of the essential constituents are present and at adequate levels, a complete evaluation of the patient must be done prior to the engagement of a wound care treatment plan.

PATIENT ASSESSMENT

The patient who presents with a non-healing wound often has a complex medical history. It is for this reason that treatment of a complicated wound should be done with a team approach. The physician primarily taking care of the wound should not be the only physician seeing this patient regularly. The "wound care team" will often include, but not be limited to a podiatrist and/or orthopedist, vascular surgeon, plastic surgeon, internal medicine physician, endocrinologist, infectious disease specialist, nutritionist, psychiatrist, and home health care nurse. The patient's medical management must be maximized and fine-tuned for optimal wound healing to occur.

The patient workup should start with vascular studies. Of primary importance is the adequacy of peripheral perfusion. Non-invasive studies should include capillary filling time, blood pressure indices, and Doppler analysis, as well as transcutaneous oximetry. These studies are helpful in predicting successful wound healing.[5] If perfusion is found to be a problem, and the patient is an adequate candidate, he or she may undergo angiography and surgery in an attempt to improve vascularity to the area. Without adequate perfusion, the essential nutrients, blood cells, and oxygen can not be delivered to the wound.

The patient's nutritional status also needs to be evaluated. Throughout the phases of wound healing, vitamins, minerals, proteins, fats, and sugars are often rate-limiting constituents. A complete blood cell count as well as blood chemistry profile is needed. Serum albumin is a sensitive indicator of the protein pool. A moderate to severe protein deficiency prolongs the substrate phase and impairs fibroplasia.[6,7] Vitamin A among other things aids in wound debridement and the stimulation of fibroblast differentiation. A zinc deficiency can delay closure of wounds and ulcers and decreases the tensile strength of collagen. A zinc deficiency can also have a detrimental effect on the immune system.[6,7] Vitamin C is required for the hydroxylation of proline in the synthesis of collagen while iron is absolutely essential for everything from the production of DNA to an essential ingredient in the production of collagen. One can easily extrapolate from these few examples, the significant need for a patient's nutritional status to be at an adequate level. All too often the nutritional assessment of the patient is ignored.

Endocrine pathologies are often a complicating factor in wound healing. A hyperglycemic state can impede cell function. Therefore diabetic patients need to have their blood sugar levels under tight control. Also, delays in wound healing have been shown as a result of a hypothyroid state. If a patient gives a history of symptoms indicating thyroid problems, this should be investigated and remedied immediately. Again, it can not be overemphasized that all treatable problems be addressed and any chronic illnesses be under control to provide an optimal environment for wound healing.[1-7]

Although uncommon, a case of patient sabotage or a Munchausen-type syndrome might be considered if a patient's vascular, nutritional, endocrine, and immune systems are good and appropriate treatment of a wound is instituted without progression of healing or even worsening of the wound. The author has experienced such cases. Valuable information might be obtained

through careful questioning of family members, friends, or home health care staff. At this time a psychiatric consultation is in order.

HYPERBARIC OXYGEN

Despite many years of use in medical settings, Hyperbaric Oxygen (HBO) remains a controversial therapy. Even though substantial evidence exists that HBO may have a therapeutic effect in certain carefully defined disease states, many practitioners remain unaware of these findings or are concerned about using HBO because of the controversy it has engendered.[8] HBO therapy is regularly used for the treatment of air emboli, carbon monoxide poisoning, crush injuries, decompression illness (the bends), traumatic and chronic ischemia, necrotizing fasciitis, brown recluse spider bites, radiation damage to bone and soft tissue, burns, and to enhance skin grafts and flaps.[5,8-13] Although all of these entities have a common overlapping pathology, for the sake of this discussion, we will only concentrate on its effect on wound healing.

HBO therapy is a treatment in which a patient breathes 100% oxygen while exposed to increased atmospheric pressures in a treatment chamber. This necessitates that the entire patient be enclosed in a chamber capable of tolerating increased pressure. In most cases, HBO therapy is administered once daily. HBO must also be differentiated from topical administration of oxygen, which consists of encasing a limb in a container, with oxygen applied exogenously. Topical oxygen has no physiologic or pharmacologic similarities to HBO.[5] Inspired oxygen is essential for all aspects of wound healing from the hydroxylation of proline in collagen synthesis, to the decontaminating ability of wounds by white blood cells.

HBO therapy is based on two physical factors derived from Boyle's law and Henry's law that state that at a constant temperature, a given volume of gas is inversely proportional to its pressure. Therefore, if the pressure is doubled, the volume of the gas is halved.[5,9,11-13] As a result, when the patient breathes oxygen while atmospheric pressure increases during hyperbaric compression, more oxygen is dissolved in the plasma and hence delivered to tissues.

Hemoglobin is the principal source of oxygen transport while plasma is a secondary carrier of oxygen to tissue. HBO increases the oxygen concentration of both hemoglobin and plasma with a greater effect on the plasma. HBO can allow a wound's oxygen demand to be met entirely from the plasma alone.[5,11,14]

Besides aiding in the oxygenation of problem wounds, HBO also has an antibacterial effect. In poorly oxygenated wounds, leukocytes are unable to obtain adequate oxygen to produce intracellular high energy oxygen radicals, which are necessary for killing wound pathogens.[5] In addition to improving leukocyte bacterial killing, HBO has direct lethal effects on anaerobic and microaerophilic aerobic organisms. Studies have shown that oxygen was essential for killing certain species of phagocytosed bacteria, such as Staph, Salmonella, Proteus, E. coli, and Klebsiella. In addition to its effect on leukocytes, oxygen augments the bactericidal action of various antibiotics such as aminoglycosides and increases the effectiveness of sulfonamides. Vancomycin also does not kill microorganisms well under low oxygen tension.[5]

HBO appears to have been tailor-made for, and has been used for a number of years in the treatment of diabetic wounds. This is because diabetic wounds are polymicrobial, with a high incidence of anaerobic organisms which cause tissue necrosis and ultimately decrease tissue oxygen levels. HBO increases tissue oxygen levels, increases host antimicrobial defense, promotes wound healing, and is directly toxic to anaerobic organisms.[5]

HBO is indicated in the patient for whom medical management with local wound care has failed. Patients with decreased transcutaneous oxygen levels can greatly benefit from HBO. HBO has been shown to aid in the healing of wounds where the TcPO2 levels are between 20 to 40 mmHg. Wounds with TcPO2 of less than 10 mmHg do not have a good prognosis even with the use of HBO.[5,9-11,13,14]

The only absolute contraindication to HBO is pneumothorax. Any air-trapping lesions in the lungs, such as cysts or bullae, need to be evaluated carefully. Active asthma is a relative contraindication as HBO should be delayed if possible until wheezing has resolved. Chronic sinusitis and upper respiratory tract infections should also delay treatment until the infection is resolved. Patients with congestive heart failure should be treated with caution, as high dose oxygen under hyperbaric

conditions will cause vasoconstriction and increase the total peripheral resistance and cardiac work.[5]

In summation, HBO increases the killing ability of leukocytes and is lethal to certain anaerobes, maintains tissue oxygenation in the absence of hemoglobin, stimulates fibroblast growth, increases collagen formation, and promotes more rapid growth of capillaries.[12] It appears that HBO will not heal normal wounds more rapidly, but may under certain circumstances, induce problem wounds to heal more like normal ones.[14]

PROCUREN & TOPICAL GROWTH FACTORS

Topical growth factors are an area of recent advanced wound healing technology. Procuren or Platelet Derived Growth Factor (PDGF) has reached wide acceptance and is commonly used in wound care centers today. There are actually five different platelet derived growth factors currently in use for the treatment of non-healing wounds. They are PD-ECGF (Platelet Derived Endothelial Cell Growth Factor), PD-EGF (Platelet Derived Epidermal Growth Factor), TGF-ß (Transforming Growth Factor-beta), PF-4 (Platelet Factor 4), and PDGF or Procuren (Platelet Derived Growth Factor). These factors are obtained when whole blood is centrifuged, and everything but the plasma is removed. The platelets in the plasma are then treated with thrombin which causes them to release these factors. These factors are further separated while the spent platelets are removed. The growth factors and proteins are then suspended in a buffered solution that is placed in vials and frozen. The factors are then taken directly from these vials and applied topically.

PDGF has been found to induce mitosis and cause chemotaxis of leukocytes, fibroblasts, and smooth muscle cells.[2,15-18] PDECGF has been shown to have chemo-attractant qualities, as well as stimulate the growth of endothelial cell and angiogenesis while PDEGF has been shown to increase collagen synthesis and serve as a chemo-attractant for epidermal skin cells. PF-4 has been shown to be a chemo-attractant for cells such as neutrophils and monocytes. TGF-ß stimulates fibroblasts to increase collagen production increasing the intracellular matrix. It also is a chemo-attractant to monocytes.[2,15,16,17,18]

Topical application of these growth factors is indicated in patients with either a suppressed healing response, marginal perfusion but are not candidates for reperfusion, or fail to develop quality granulation tissue secondary to diabetes or related illness.[7,16] The growth factors are contraindicated in patients with hepatitis, HIV, or the presence of cancer.[7] While research and studies into these factors are currently taking place, they appear to have a benefit in the select patient. One of the limiting factors for the use of these factors has been the cost. Proponents argue that the savings from decreased hospital time, wound care treatment time, and the return of the patient to work would actually save money. Again, it can not be overstated that any of the modalities discussed as with growth factors are only a part of the process in the care of the non-healing wound. None of these modalities are an end all or cure for the non-healing wound (Table 1).

WOUND DRESSINGS

Sodium & Calcium Alginates

Alginic acid is extracted from different species of brown seaweed. Alginates are salts of alginic acid. Although little research has been performed using alginates, clinical studies have shown they encourage wound healing which is believed to be a result of their promotion of granulation and epithelialization of wounds.[1]

Because of the conformability of alginates, wound shape or size is not a limiting factor for their use. They absorb wound exudate and are useful in deep cavernous wounds and fistulas. They are one of the only synthetic materials indicated for such, because alginates are easily flushed from the wound at dressing changes and if any remains in the wound it will be broken down and metabolized by the body.[1,2] Alginates are manufactured in both rope and pad forms which are extremely light weight and can absorb several times their weight.[2] After absorbing exudate, the alginates form a water vapor permeable, gel-like covering, which helps maintain a moist healing environment. Due to their absorptive nature, alginates have a tendency to excessively dry lightly exudative wounds, and are therefore not indicated for such.[2] Disadvantages include the need for a secondary dressing, some require mixing, and they lack the capacity to debride eschar.

Table 1

GROWTH FACTORS

FACTOR	ACTION	CELL INTERACTION	FUNCTION
PDGF	Mitogen Chemoattractant	Fibroblast & Smooth Muscle Cells & Leukocytes	Produces extra-cellular matrix
PDEGF	Mitogen Chemoattractant	Epidermal Cells	Produces epidermal skin
PDECGF	Chemoattractant	Endothelial Cells	Restores Vascular System
PF-4	Chemoattractant	Monocytes & Neutrophils	Eliminates Debris & Bacteria
TGF-b	Chemoattractant & Synthesis of cellular Matrix	Monocytes & Fibroblasts	Strengthens Maxtrix & Fights Infection

Hydrocolloids

Hydrocolloid dressings consists of an inner, thick absorbing hydrocolloid layer and an outer, thin, water-resistant polyurethane film. Once the dressing is in place, exudate collects under it between the wound itself and the dressing. The exudate produced is often foul-smelling and pus-like and may be mistaken for infectious exudate. It does take some time getting used to the appearance of the exudate on the dressing by both the doctor and patient. As previously stated, people who do not have experience using hydrocolloids often mistakenly think the wound is infected upon removal of the dressing. Due to the polyurethane backing, hydrocolloids are water-resistant but allow evaporation of collected fluid.[1] Hydrocolloids are indicated in the treatment of pressure ulcers (stage 1,2,3), vascular ulcers, and minimal to moderate exudative wounds.

Hydrocolloids promote fibrin breakdown, increase keratinocyte proliferation, encourage epidermal migration, and protect against contamination, while absorbing a fairly large volume of exudate.[1] Hydrocolloids are comfortable, easy to apply, and may be worn in the shower. Since they are impermeable to water, they may cause peri-wound maceration.[2] Other disadvantages include the inability to visualize the wound, and the possible destruction of new epithelial tissue with removal of the dressing.[1] Since the dressing is so absorbent, the frequency of changes can be anywhere from 1 to 5 days. Hydrocolloids are available in a variety of sizes, shapes, and thicknesses as well as sheets, granules, pastes, and powders.[1]

Hydrogels

Hydrogels are lattices of cross-linked polymers that act as a sponge to provide a wicking effect for the wound exudate. The back of the dressing contains a semipermeable film that allows transmission of water vapor, oxygen, and carbon dioxide while maintaining a moist wound environment. Some are packaged with a film that adheres the dressing to the body while others require a second dressing to keep them in place.[1] The advantages of hydrogels include absorption of wound exudate, moderate ease of application, and encouragement of a moist wound environment. The disadvantages include difficulty keeping the non-adherent type of dressing in place as well as requiring secondary dressings to secure the hydrogel. Hydrogels have also been indicated in the possible encouragement of some forms of G-organisms.[1] Dressing changes occur every 1 to 3 days depending on the amount of exudate. They are useful for shallow abrasions, blisters, and superficial wounds. They are available in sterile and nonsterile sheets and amorphous gels. The gels have the added ability to create moist environments in otherwise dry wounds and some have additional capabilities of wound debridement and exudate absorption.[2]

Foams

Foam dressings are composed of a highly absorbent hydrophilic polyurethane, and backed with a semipermeable film which allows for the transmission of gases and vapors while helping to maintain a moist environment.[2] These dressings are thin, and can absorb small amounts of wound

exudate. They are two-sided with a hydrophilic portion that is placed on the wound, and a outer hydrophobic area that is covered with a secondary dressing.[1] Foam dressings do allow oxygen and vapors to transmit while maintaining a moist environment.[2] Some foams contain bacteriostatic, cleansing and moisturizing agents.[1] Advantages include conformability and comfort, while the disadvantages include need for an additional dressing, limited amount of absorbency and possibility of bacterial contamination. Foams come in sheets of varying sizes and thicknesses. The amount of exudate produced by the wound dictates how often these dressings need to be changed. Foams are commonly used for exudative wounds such as venous stasis ulcers.[2]

Films

Film dressings are thin, elastic sheets of polyurethane. They are transparent and semipermeable to vapor, but their outside surface is waterproof. When using film dressings, one must be careful of channeling. Although the circumference of the dressing is adherent to the surrounding skin, channels may develop that allow water and bacteria to enter the wound site.[1]

Advantages of this dressing include the ability to visualize the wound, can be used as secondary dressing to hold a primary dressing in place, and they are very effective for superficial wounds, skin donor sites, and blisters. Disadvantages include channeling, possible periwound maceration, and difficulty in use because of their flimsy nature. When they are entirely adhesive they can stick to themselves and make channels or complicate proper placement. They can also strongly adhere to surrounding skin, so removal should be done carefully especially with someone with fragile skin such as the elderly. Films are non-absorbent, therefore contraindicated for sole use in moderate or highly exudative wounds. When used appropriately changes need to occur every 2 to 3 days (Table 2).

ENZYMATIC AGENTS

Enzymatic ointments can be used to soften and remove necrotic debris, superficial, devitalized tissue as well thick, fibrotic tissue that may be impeding the development of healthy granulation tissue (Table 3). It in no way should take the place of regular surgical debridement but can be used as an adjunct particularly in the non-surgical patient. Several different types of enzyme ointments are available including collagenases, deoxyribonuclease, papains, and sutilains. Care must be taken to protect surrounding tissue when using these

Table 2

BRAND NAMES OF DRESSINGS

ALGINATES	HYDROCOLLOIDS	HYDROGELS	FOAMS	FILMS
Kaltostat	Duo-derm	Carrysyn Gel	Mitraflex SC	Acu-Derm
KaltostatFortex	Cutinova Hydro	Carrysyn V	Mitraflex	Bioclusive
Sorbsan	Tegasorb	Aquasorb	Allevyn	Opsite
Algosteril	Hydrapad	Elastogel	Epilock	Polyskin II
Chronicure	Intact	Hydron	Flexzan	Pro-Clude
Curasorb	Intrasite	Intrasite Gel	Lyofoam	Tegaderm
*Dermasorb	J&J Ulcer dressing	NU-GEL	Lyofoam T	Tegaderm HP
	Restore	Vigilon	Nu-Derm	Transite
	Replicare	Clear-Site	Polymem	Uniflex
	Triad	NormiGel		Blisterfilm
	Ultec	Royl-Derm Hydrogel		Ventex
		Solosite		
		WounDres		
		SAF-Gel		

*Dermasorb is a combination of an alginate and a hydrocolloid (by Convatec)

products as these enzymes do not differentiate between healthy and necrotic tissue. The surrounding skin should be protected with petroleum jelly.[7] Also, collagenases should not be applied to wounds that have been cleansed with soaps, detergents, or metallic ions since all can inactivate the enzyme. Irrigation of the wound should be done with normal saline if collagenase will be added.[2]

Table 3

ENZYMATIC AGENTS

COLLAGENASES
Santyl
Granulex
Trypsin
Fibrinolysin

DEOXYRIBONUCLEASES
Elase
PAPAIN
Panafil

SUTILAINS
Travase

WOUND CLEANSING PRODUCTS

This is one area of wound care that often shows a general lack of current knowledge by many physicians who treat wounds. Often, the physician uses wound cleansing protocols they used while a student in clinic. This is in spite of studies that have shown that products such as acetic acid, povidone-iodine (Betadine), Hypochlorite (Dakin's), or chlorhexidine (Hibiclens) are cytotoxic and detrimental to newly formed fragile granulation tissue. In fact, one study demonstrated that not until a dilution of povidone-iodine was down to 0.001% did it retain some bacterial effect without being cytotoxic.[17] While some of these products' antibacterial effect might be desired, they should be used judiciously. There are several non-toxic products on the market today that claim to have an antimicrobial effect while being nonirritating to a wound (Table 4).

Table 4

WOUND CLEANSING PRODUCTS

NON-IRRITATING
Cara-Klenz: non-toxic cleanser

Curasol: non-toxic cleanser

Biolex: non-toxic cleanser

Saline: flushing and irrigation

ShurClens: non-toxic and no rinsing needed

Techni-Care: non-staining while killing G+, G-, MRSA, and pseudomonas

Royl-Derm Cleanser: antimicrobial and no rinsing needed.

Clinical Care: Kills E. coli, S.aureus, MRSA, and pseudomonas.

Silver Sulfadiazine: antimicrobial including G+, G-, MRSA, pseudomonas, E.coli, Strep., Candida albicans

CYTOTOXIC
Hydrogen Peroxide: can cause an air emboli deep wounds or sinuses.

Hypochlorite: can irritate surrounding tissue. Is effective against Staph.

Povidone-Iodine: bacteriocidal but cytotoxic to fibroblasts.

Chlorhexidine: only use on intact skin

Acetic Acid: pseudomonal action in superficial wounds

DISCUSSION

From this brief overview of wound healing and wound care products one can easily feel overwhelmed. If you stick to certain basics and develop a general working knowledge of certain wound care products, you can develop successful treatment plans for the different types of complicated wounds that might present to you. First and foremost the etiology of the wound must be identified. Too often this is ignored and wounds are treated for extended periods of time with the only result being frustration of the physician and patient. If the wound is a result of venous stasis, then compression is needed. If there is osteomyelitic bone under a wound, chances are it will not heal or will continue to breakdown until the infected bone is removed. If decubitus ulcers are present, the pressure must be relieved, and if the wound is a result of ischemia, something needs to be done to increase the perfusion to the area.

Wound care management is a team approach. Do not be the only physician that the patient sees regularly. Non-healing wounds almost always involve some other disease or illness. A complete vascular and nutritional assessment is a must, and if at all possible, try and get the patient actively involved in their own treatment.

Another important segment of wound management is accurate record keeping. The author would highly advise taking a picture of the wound on initial presentation as well as periodically throughout the healing process. Always measure your wounds in both diameter and depth and note any changes in color, exudate, smell, and size. Keeping track of this information is not only important in the medical-legal sense, but also allows you to develop a general awareness of how long it takes for certain type and size wounds to heal. Pictures also make a great tool to show patients so they can know what to anticipate.

As stated earlier, there are literally hundreds of wound care products available today. It is almost impossible to keep up with them. A good way to keep informed is to ask associates and colleagues what they are doing for wound care. Never be afraid to change a treatment regimen if you are not getting satisfactory results. While healing of a chronic wound is a time-consuming process, too often patients undergo the same care for months to years without any progression of their wound. Also if appropriate wound management is given without signs of healing, it may be time to biopsy the wound as certain cancerous lesions, such as squamous cell carcinoma masquerade as non-healing wounds.

Wound care management is a dynamic field with some promising research being done today. A simple understanding of basic wound healing principles as well as treatment modalities and products available to you should enable you to be a valuable constituent on the wound care team.

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