Chapter 2
Improving Outcomes in Wound Healing

Wound healing can be impaired by a variety of wound-specific factors including the presence of bacteria, debris, and/or devitalized tissue. Other factors which affect wound healing are patient conditions that can result in decreased function of immune cells and poor oxygenation of tissues, such as smoking, diabetes, peripheral vascular disease, poor nutritional status, steroid, and immune-modulating or cytotoxic drugs. These and other factors can contribute to poor blood flow and wound ischemia, resulting in poorly healing wounds and dehiscence.

2.1 Local Wound Environment

In the primary assessment and prior to wound closure, you must establish that the wound is free of excessive contamination or devitalized tissue. The reason for this is simple; devitalized tissue, foreign bodies, and excessive contamination will increase the chances of wound infection. Wound infection can lead to increased inflammation, scarring, wound dehiscence, prolonged healing, severe cellulitis, and decreased functionality. Wound irrigation is the most important aspect of wound preparation as it is the primary way that excessive contamination is removed from acute traumatic wounds [12]. The process of adequate irrigation and debridement will be covered again later in the text. Multiple studies have attempted to determine the optimal method and amount of irrigation needed to significantly reduce bacterial load and risk of infection. So far there has been a clear benefit demonstrated in irrigation versus no irrigation, but no specific method has been shown to have a statistically significant benefit over any other method [12]. For this reason, I recommend a simple syringe-based method for pressurized irrigation of the wound. Prior to infiltration of anesthetic, cleanse the wound edges using chlorhexidine gluconate (Hibiclens) or povidone-iodine diluted in water or normal saline. Take care not to get these agents in the wound as they can cause pain and disruption of the cellular components necessary for wound healing. After the wound has been anesthetized, irrigate

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the wound with normal saline solution. Pressure irrigation can be performed using a syringe and a splatter shield. Depending on the size of the wound, 100–200 cm^3 of fluid should be utilized for adequate irrigation. At this point foreign material still remaining in the wound can be removed with a forceps, and devitalized tissue can be removed using a forceps and tissue scissors.

Cleansing Around a Wound

- Hibiclens or iodine (do not use Hibiclens near the mouth or eyes).
- Cleanse three times with a new sterile gauze or swab soaked in the antimicrobial agent of choice.
- Cleanse from the wound in a circle extending outward.

Time of presentation of the acute wound was at one time felt to influence the local wound environment. Wounds >6–8 h old were often left open due to the fact that it was believed they represented a higher infection risk. Current research has shown this to be a false assumption [13]. Wounds can be successfully closed at less than 24 h without any additional intervention, aside from irrigation. After this point wound epithelialization may have an impact on wound closure but not infection.

2.2 Infection

Wound infections can lead to morbidity of wounds including wound dehiscence, disfiguring scarring, and delayed closures. Identifying and treating infections early can lead to improved wound closure outcomes.

During the initial treatment of the acute traumatic wound, application of a topical antimicrobial after wound closure has been shown to effectively reduce the rate of infection. The compounds most effective at preventing infection, while also minimizing associated complications, were found to be bacitracin zinc and neomycin sulfate [14].

Patients should be carefully instructed so that they know how to examine the wound daily for increasing redness, pain, swelling, or discharge from the wound site that might indicate the presence of infection. They should have the ability to return for evaluation as needed during the period between wound closure and suture removal. Patients should typically be seen 2 days after wound closure and treatment for removal of the initial dressing and assessment for wound infection. If wound infection is suspected, one or two sutures or staples should be removed, and a sterile cotton swab can be used to open the wound to probe for purulence. If purulence is expressed, the wound should be opened adequately and thoroughly irrigated to allow drainage of the infection. Antibiotics should only be given when there is extensive cellulitis of the tissues surrounding the wound (>1 cm surrounding erythema or lymphangitis).

There is no benefit to prophylactic antibiotic usage in acute wounds, and this may lead to the emergence of antibiotic-resistant organisms. In addition wounds should be carefully assessed for pathologic versus physiologic inflammation. Many healing

wounds will present with a peripheral erythema of about 2–5 mm surrounding the wound. This is not an indication of infection but simply a normal wound healing process. Prudent use of antibiotics should also be tailored to the organisms most likely to be infecting the wound. For the majority of patients, a first-generation cephalosporin (or clindamycin for patients with an allergy to cephalosporins) with activity against *Staphylococcus aureus* and *Streptococcus* sp. (such as cephalexin) is adequate. Unless the patient has known history of methicillin-resistant *Staphylococcus aureus* (MRSA) or other risk factors (multiple hospitalizations, multiple infections, IV drug use, etc.), it is not necessary to use a broad-spectrum antibiotic such as TMP-sulfa, doxycycline, or levofloxacin. The overuse of these drugs is leading to the emergence of new resistance patterns in *Staphylococcus* and *Streptococcus* species.

2.3 Age

Although systemic factors may not always be under the direct control of the provider or of the patient, efforts should be made to correct any modifiable risk factors. Age, for instance, is not a modifiable risk factor, but it should be taken into account when determining when to remove sutures from an elderly population. Advanced age leads to alterations in inflammation and cellular interactions that can prolong and impair epithelial and endothelial cell binding and interactions. This can lead to an increase in the risk of wound dehiscence in elderly patients. In a study conducted on otherwise healthy human volunteers, it was determined that patients over the age of 70 required an additional 1.9 days of healing compared to a younger population of patients [15].

In addition, many elderly patients may suffer from comorbid conditions that negatively affect wound healing such as cardiovascular disease, diabetes, nutritional deficiencies, and autoimmune diseases and may take a variety of medications that may or may not be known to impair wound healing and collagen integrity such as immune-modulating agents and corticosteroids. For this reason it may be prudent to allow 2–4 additional days for wound healing or to apply adhesive strips for added wound support following the removal sutures from acute wounds in elderly patients.

2.4 Local Tissue Hypoxemia

Poor oxygenation of tissue can have a deleterious effect on wound healing. Poor oxygenation impairs the function of neutrophils and can result in increased infection and dehiscence rates of wounds [16]. The number one modifiable risk factor to improve oxygenation in wound healing is cessation of tobacco use.

Collagen synthesis requires oxygen as a cofactor and local tissue hypoxemia can lead to loss of epithelial integrity. Nicotine is a highly vasoconstrictive compound

that has been shown to prolong the healing time of wounds in otherwise healthy indviduals [17]. Tissue hypoxemia from blood vessel constriction due to tobacco use can also impair the function of fibroblasts, thereby decreasing collagen synthesis and cross-linking. Patients who smoke also tend to suffer from higher rates of wound complications such as infection and dehiscence due to impaired cellular mechanisms and collagen cross-linking as described.

Other factors that can lead to decreased tissue oxygenation are tissue edema and excessive tension on the wounds. For wounds on edematous extremities, patients should be counseled on compression and elevation of affected extremities, and efforts should be made to control underlying diseases such as heart failure. Excessive tension is under the direct control of the provider. Oftentimes direct tension on the wound can be alleviated by disruption of the subcutaneous fibrous connections between the dermis and the subdermal components.

2.5 Diabetes

Uncontrolled diabetes has a number of detrimental effects on wound healing, and diabetic patients should understand the added importance of good glucose control during the healing period. It is the number one metabolic disorder that affects wound healing as it has detrimental effects on oxygenation, growth factor signaling, neovascularization, and immune function [18]. Poorly controlled diabetes decreases the number and availability of small blood vessels contributing to tissue hypoxemia. In addition glycosylation of proteins decreases the overall amount of growth factors and signaling proteins available during the inflammatory phase of wound healing. Impaired glucose utilization also negatively impacts neutrophils and fibroblasts leading to increased risk of infections and decreased collagen synthesis.

2.6 Nutrition

The importance of nutrition as a modifiable risk factor should not be overlooked, especially in elderly, frail, or chronically ill patients, some of which may present to an urgent care with an acute or chronic wound for evaluation [19]. Patients may also inquire of you how to improve their own outcomes both in terms of wound integrity and decreased scarring. It is important to counsel patients that adequate protein intake has been correlated with improved outcomes in wound healing and repair, although increase in the amount of protein ingested does not correlate with improved healing. Ensuring that patients are not significantly malnourished at the time of presentation (especially in the elderly and those completely dependent upon others for care) is more important than advising patients to take in an excess of protein.

In addition, vitamins A and C are necessary cofactors for wound healing and collagen synthesis. Deficiencies in protein, vitamin A, and vitamin C have been

linked with increased rates of infection as well as poor wound healing and dehiscence. Vitamin C supplementation, however, has not been shown to improve wound healing. This is likely because vitamin C is a water-soluble vitamin, and excess amounts will be lost in urine. Vitamin A supplementation of 25,000 to 100,000 IU have been advocated to improve wound healing, decrease infection by increasing the effectiveness of the inflammatory phase of wound healing, and increasing collagen synthesis and epidermal cell replication and growth even in non-deficient healthy populations [20]. Vitamin A has also been shown to improve impaired wound healing in patients currently taking steroids [21] or those who have diabetes and other chronic illnesses.

Another trace element that has been studied extensively in wound healing is zinc. Zinc is a critical cofactor for a number of enzymes that are integral to wound healing [22]. Many critical aspects of wound healing are impaired in zinc-deficient patients, but at this time there has been no clear benefit shown to zinc supplementation in normal, non-deficient patient populations.

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Busse, B.

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