Summary Article: Overview of Wound Healing: Anatomy and Physiology
From Essential Procedures for Practitioners in Emergency, Urgent, and Primary Care Settings

SKIN ANATOMY

Skin is a component of the integumentary system and is known as the cutaneous membrane. The cutaneous membrane consists of three major areas: cutaneous, subcutaneous, and deep fascia. It is a key component to our existence by providing protection, excretion, temperature regulation, sensory perception, and the synthesis of vitamin D. The skin also acts as a water barrier, specifically the stratum epithelial layer. Disruption in this layer can result in large water loss (i.e., burn victims).

Skin acts as a protective barrier to the external environment. It facilitates vasoconstriction and vasodilatation for temperature regulation and excretes salt, and water through perspiration. Nerve endings are encompassed to provide pain reception and the sensations of touch and pressure. Finally, skin is involved in the photosynthesis of vitamin D.

The dermal and epidermal layers comprise the cutaneous layer. The epidermis is the outermost layer and is made up of stratified squamous epithelial cells. There are two layers that are important to wound healing: the stratum germinativum, which continually makes new keratinocytes as old ones are shed (basal layer), and stratum corneum (horny or keratinized layer) layer that progressively moves up from the basal layer. The layers are very thin (0.2 mm thick) and difficult to differentiate from the dermal layer.

The dermis is the main component of the wound healing process. It is thicker and lies below the epidermis, and is made up primarily of connective tissue. The main cells of the dermis are fibroblasts, which are key in the facilitation of wound healing. They deposit fibrous proteins (elastin fibers and collagen), which give the wound its intrinsic strength. Blood vessels, nerves, and sebaceous and sudoriferous glands are contained within the loose connective tissue of this layer.

The layer lying beneath the dermis is the superficial fascia or subcutaneous layer. It is primarily composed of loose connective tissue and adipose tissue. These tissues provide insulation and protection to major blood vessels and underlying structures during trauma and significant temperature changes. Sensory nerves and major blood vessels pass through this layer.

The deepest layer is the deep fascial layer. It is composed of fibrous, thick, and dense tissue that supports the superficial layers of skin. This layer contains sensory nerve fibers, blood vessels, and lymphatics. The functions of this layer are to provide protection from the spread of infection, as well as to support and protect the underlying muscle and soft tissue structures. See Figure 10.1 for the layers of the skin.

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PHASES OF WOUND HEALING

There are three main phases of wound healing. The components of the initial inflammatory phase are hemostasis and inflammation. The second phase is the proliferative phase and the final is the remodeling phase. There are many events occurring, separately and simultaneously. These phases begin at the onset of the wound and can continue for 1 to 2 years.

Hemostasis begins in minutes immediately after the injury via vasoconstriction, activation of the clotting cascade, and platelet aggregation. The platelets release thrombin and growth factors attracting fibroblasts and monocytes to the wound and the intrinsic clotting cascade is activated. This helps to limit the initial damage of the wound by ceasing bleeding and sealing the wound surface through retraction of the wound edges and clot formation.

The inflammatory phase is characterized by activation of the complement system, which causes increased vascular permeability, migration of cells into the wound and angiogenesis. Clinically this constitutes erythema, swelling, warmth, and pain. Chemoattractant agents bring the neutrophils and monocytes to the wound within 24 to 48 hours. The neutrophils clean the area by trapping and killing bacteria. The monocytes become tissue macrophages producing growth factors and cytokines to remove nonviable tissue and bacteria. Epidermal cells begin to migrate into the wound from surrounding tissue.

Neovascularization, fibroplasia, and epithelialization are the main components of the proliferative phase. Granulation occurs during this phase and the wound edges move closer together. A loose arrangement of collagen fibers begin to fill the wound as new capillaries begin to grow.

During the maturation phase, remodeling and wound contraction begin to occur. Wound contraction occurs as a result of myofibroblasts pulling collagen toward the cell body and epithelialization is the migration of epithelial cells to resurface the wound. A more organized and stable form of collagen replaces the soft collagen. This increases the intrinsic tensile strength of the wound. This phase usually lasts about a year but can take 2 years to complete. Approximately 1 week after the wound occurs, the tensile strength is around 10% and at 1 year it can be 80%. Healed wounds never regain their original full tensile strength.

TYPES OF WOUND HEALING

Wound healing can occur by one of three ways: first intention, second intention, or third intention. First
intention is when the wound is closed with sutures, staples, skin adhesive, or Steri-strips. Closure depends on time, contamination, and tissue devitalization. These are either clean lacerations or surgical incisions.

Second intention is when the wound is left open to heal on its own. This is a slower process than first intention and allows the wound to heal through granulation from the inside outward. These wounds can be caused by abscess, ulceration, puncture, or animal/human bites that are high risk of infection if closed primarily. These wounds can be grafted or revised at a later date when the risk of infection is considered minimal.

The final method of healing that is widely underutilized is a delayed primary closure. This is also known as third intention. Wounds that are significantly contaminated may be closed 4 to 5 days after occurrence to help reduce the risk of infection. This timeframe corresponds with the stages of wound healing when the risk of infection is significantly decreased. Delayed closures can occur weeks or months after the initial injury.

FACTORS COMPLICATING WOUND HEALING

Wound healing is a complex process that can be affected by numerous factors. Trauma, extent of wound, age, type of closure, alcoholism, diabetes, connective tissue disorders, medications, vitamin deficiencies, nutritional status, and circulation are all factors affecting wound healing. Consideration of underlying factors and prevention of further damage to the wound during any interventions are key to efficient wound healing.

WOUND CARE

Wound care before and after any procedure is crucial to wound healing. All wounds require cleansing with sterile normal saline. This can be completed through irrigation, scrubbing, and soaking. The method used will be dependent upon the type and extent of contamination of the wound. The use of hydrogen peroxide and povidone iodine are controversial and cause damage to viable tissue. Anytime these substances are used, they should be diluted. Whenever possible, commercially prepared skin cleanser should be used (i.e., chlorhexidine). Skin cleansers should also be used before any infiltration or invasive procedure to limit contamination with normal skin flora, dirt, and debris.

Author’s Pearls

- Wounds that are delayed in their healing or become worse have three general possibilities for the cause: retained foreign body, infection, and cancer.
- Pink or beefy red granulation tissue is a sign of proper wound healing and represents the proliferation phase.

TYPES OF WOUNDS

There are six categories of wounds, which include abrasion, avulsion, combination, crush, laceration, and puncture. The characteristics and extent of the wound are dependent on the causative force. Please see Table 10.1 for the description of wounds in each of these categories and their causative force.
TABLE 10.1 Description of Wounds

<table>
<thead>
<tr>
<th>Classification</th>
<th>Force</th>
<th>Wounds Characteristics</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abrasion</td>
<td>Skin and object in opposite directions</td>
<td>Rough appearance with loss of epidermis and superficial dermis</td>
<td>“Road rash”, “skinned knee”</td>
</tr>
<tr>
<td>Avulsion</td>
<td>Shearing Tensile force</td>
<td>Partial or complete loss of skin layers</td>
<td>Skin tear Flap of skin</td>
</tr>
<tr>
<td>Combination</td>
<td>Multiple forces cause wound: Crush, shear, tensile</td>
<td>Takes on numerous appearances depending on the force</td>
<td>Compression injury Explosions Motor vehicle crash</td>
</tr>
<tr>
<td>Crush</td>
<td>Compression of tissue against hard surface or bone</td>
<td>Devitalized tissue Ecchymosis surrounding wound</td>
<td>Rough, jagged wound edges</td>
</tr>
<tr>
<td>Laceration</td>
<td>Shear Compression Tensile</td>
<td>Clean, tidy Rough, jagged</td>
<td>Incision Knife injury Hitting head on solid object</td>
</tr>
<tr>
<td>Puncture</td>
<td>Tensile, compression</td>
<td>Depth of wound is greater than width Inability to visualize end of wound</td>
<td>Stepping on nail Bites</td>
</tr>
</tbody>
</table>

WOUND MANAGEMENT

General care of all wounds presented throughout this book should be followed. Cleaning the skin with a skin cleanser (diluted povidone iodine or chlorhexidine) should be done before any injection procedure. Remember, the solution for pollution is dilution! Open wounds presenting to the provider should always be irrigated with normal saline before progressing with any procedure. It would be redundant to list this for each procedure involving an open wound. If a specific method of wound cleaning is necessary, then it will be noted in the respective chapters.

SPECIAL CONSIDERATIONS

Ring Removal

BACKGROUND

Any injury to the upper extremity can cause swelling to the finger(s). For this reason all rings should be removed before swelling begins. In cases where the edema has begun, the ring(s) can be removed using one of three techniques: lubricant, string technique, and ring cutter. Patients’ rings not only have financial value but also sentimental value. For these reasons attempts at removal with lubricant and/or string should be made before resorting to a ring cutter. Some metals are very strong, (i.e., Tungsten) and difficult to cut through and may lead to further injury of the digit (i.e., lacerations, edema).

PROCEDURAL PREPARATION

Lubricant

- Gloves
- Water-based lubricant (K-Y Jelly)
- Gauze or paper towel

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String Method
- Gloves
- Wide width Penrose drain or tourniquet
- 20 inch length of string, umbilical tape, or 1/4 inch packing

Ring Cutter
- Gloves
- Manual or powered ring cutter

PROCEDURE

Lubricant
- Liberally apply lubricant to the finger and rub around the ring
- Turn the ring in a circular motion (one direction only)
- Apply traction, moving the ring off the finger past the proximal interphalangeal joint
- Clean the finger with gauze or paper towel

String Method
If there is significant trauma to the finger or the patient is apprehensive and anxious, a digital block can be performed before beginning this procedure (see Anesthetic Agents and Procedures for Local and Field Infiltration).

- Take the penrose drain, or tourniquet, and wrap it around the finger distal to proximal
- Allow it to stay in place for a few minutes (Figure 10.2)
- Remove the penrose drain and pass the string material between the finger and ring
- Wrap the string from as close to the ring as possible distally on the finger
- Begin to unwrap the string from the proximal end (Figure 10.3), which will begin to move the ring off the finger

FIGURE 10.2 Ring removal—penrose-tourniquet application.

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Ring Cutter

- Place the hook end of the cutter between the ring and finger (Figure 10.4)
- Allow the wheel to rest on the ring
- Begin turning the handle if the cutter is manual or start the power on the power cutter
- Once through the ring, attempt to spread the metal
- If the ends of the metal are too difficult to spread, another cut may be necessary

EDUCATIONAL POINTS

- Advise the patient that the ring can be repaired by a jeweler

Author's Pearls

- Give reassurance and encouragement during the procedure
- Ask if there are any inscriptions in the ring and try to avoid that area if possible
- Manufactured ring cutters can either be manual, electrical, or battery operated (Figure 10.5)
RESOURCES


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