CHAPTER 5

WOUNDS

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A wound can be defined as a disruption of the normal anatomical relationships of tissues as a result of injury. The injury may be intentional such as a surgical incision, or it may be accidental following trauma.

I. STAGES OF WOUND HEALING

Wound healing is a complex, highly-regulated, multiphase process involving inflammation, fibroblast proliferation, and remodeling in the setting of tissue injury. Wounds may progress or even regress through these stages based on local and systemic factors.

A. Inflammatory phase (typically 1-4 days, if primarily closed)
    1. Physiology of inflammation
        a. Cytokine release is initiated by affected tissue cells and blood clot, which promotes recruitment of platelets and macrophages to the site of injury
        b. Leukocyte margination and emigration through neighboring vessel walls
        c. Venule dilation and lymphatic blockade
        d. Neutrophil chemotaxis and phagocytosis
    2. Presence of foreign material, bacterial load, and extent of devitalized tissue and bleeding modulate the body's inflammatory response to tissue damage
    3. As long as the wound remains open, wounds remain in this phase. Reestablishment of epithelium or wound closure is important in order to progress through the remaining phases of wound healing.
B. Proliferative phase (days 4-42)
    1. Platelet degranulation initiates the proliferative phase of wound healing by establishing a fibrin clot that can be used as a scaffold to support angiogenesis and extracellular matrix formation
    2. Synthesis of collagen tissue from fibroblasts
    3. Increased rate of collagen synthesis for 42-60 days
    4. Rapid gain of tensile strength in the wound
C. Remodeling phase (4 weeks-1 year)
    1. Provisional tissue regenerated in the proliferative phase is revised through cellular apoptosis and expression of matrix metalloproteases.
    2. The extracellular matrix and subsequent scar is reorganized largely in response to mechanical tension, inflammation, and genetic phenotype
    3. Maturation by intermolecular cross-linking of collagen leads to flattening of scar
    4. Requires approximately 9-12 months in an adult, longer in children. (Scar revisions may be delayed a year or longer after injury to ensure remodeling is complete.)

5. Tensile strength of a healed scar will peak at approximately 60 days post-injury and achieve up to 80% strength of unwounded skin

II. FACTORS INFLUENCING WOUND HEALING

A. Local factors
   1. Fluid collection: hematoma or seroma
   2. Early wound closure
   3. Blood supply
   4. Temperature
   5. Infection
   6. Technique (gentle handling of tissues, orienting incisions or closures along optimal vectors to disperse mechanical tension) and ideal suture materials
B. Systemic factors – optimize nutrition, palliate or optimize chronic illness, deleterious effects of medications that interfere with wound healing (chemotherapy, steroids, etc.)

III. WOUND CLOSURE

Several general surgical principles are important to keep in mind to expedite wound healing and reduce the incidence of hypertrophic or pathologic scarring. Approaches to wounds should always include adequate debridement, removal of any nonviable tissue and foreign bodies, bacteriologic control, and optimization of systemic factors governing wound healing.

A. Healing by primary intention - wound closure by direct approximation, pedicle flap or skin graft
   1. Debride necrotic or nonviable tissue and irrigate copiously to expedite inflammatory phase
   2. Dermis should be accurately approximated. Skin glue may be used if the wound is limited to partial thickness depth
   3. Scar may be red, raised, pruritic at peak of collagen synthesis
   4. Scar remodeling occurs over approximately 9-12 months in adults, as collagen maturation takes place (may take longer in children)
   5. Final result of scar is dependent on length of time until definitive wound closure, location, and mechanical tension, and factors influencing amount of inflammation.
B. Healing by secondary intention – wound is left open to heal
   1. Myofibroblasts promote contraction of wound edges
   2. Epithelialization proceeds from wound margins towards center at 1 mm/day under ideal circumstances
   3. Secondary healing beneficial in heavily contaminated or “dirty” wounds (e.g. perineum), or wounds in areas that have excellent vascular supply (e.g. scalp)
C. Healing by tertiary intention - delayed wound closure after several days

1. Intentional interruption of healing started as secondary intention
2. May proceed any time after granulation tissue has formed in wound
3. Delayed closure should be performed when wound is not infected. Quantitative culture should demonstrate <100 CFU bacteria/gram of tissue
4. Skin grafting may be considered in larger wounds for definitive closure after adequate debridement and presence of well-vascularized wound bed

IV. MANAGEMENT OF THE CLEAN WOUND

A. Aim to obtain a closed wound as soon as possible to prevent infection, fibrosis and secondary deformity
B. General principles
    1. Updated tetanus vaccine. Administer if not within 10 years of booster for clean minor wounds or within 5 years for contaminated wounds
    2. Local anesthesia - use lidocaine with epinephrine unless contraindicated
    3. Tourniquets may help provide bloodless fields in extremities
    4. Surgical prep
        a. Aqueous-based:
            i. Povidone-iodine: one of the few products that is widely effective and safe on nearly all skin surfaces. Must be diluted 1:1 with normal saline when used around the eyes
            ii. Chlorhexidine gluconate (CHG): more sustained antimicrobial activity and more resistant to neutralization by blood products than iodine. Contraindicated on genitalia and open wounds
    5. d. Alcohol-based:
            i. Ethyl and isopropyl alcohol: quick, sustained, durable, with broader spectrum antimicrobial activity
            ii. When used alone, alcohol is fast and short acting, has broad-spectrum antimicrobial activity, and is inexpensive. Can also be combined with iodine or CHG.
            iii. Highly flammable
            iv. Contraindicated on open wounds and genitalia
    6. Debridement and irrigation - Remove clot, debris, and necrotic tissue. Copious irrigation to remove debris and decrease bacterial inoculum
    7. Closure - approximate dermis as atraumatically as possible, consider undermining of wound edges to relieve tension
    8. Dressing - must provide absorption, protection, immobilization, even compression, ideally without interfering with function
C. Types of wounds and their treatment
    1. Superficial abrasions - cleanse to remove foreign material and apply moist dressings or ointments to provide moist environment for re-establishment of epidermis
        a. Remove gross debris buried in dermis within 24 hours of injury to prevent infection, prolonged inflammation, and traumatic tattoos

2. Contusion - evacuate soft tissue hematoma if a fluctuant, organized collection is present or if pressure of hematoma is compromising surrounding tissue (ears, nailbed, etc).
    a. Early - minimize by cooling with ice (24-48 hours)
    b. Later - warm compresses helpful to speed reabsorption of blood
3. Laceration - revise and trim wound edges as necessary, debride, and suture
4. Avulsion
    a. Partial - revise and suture the flap if viable
    b. Total - avulsed tissue may be irrigated, cleansed, defatted, and applied as a full thickness skin graft
5. Puncture wound - evaluate underlying damage, possibly explore wound for foreign body, and obtain x-ray if appropriate. If small, consider leaving open or partially open to promote egress of drainage
6. Bullet wounds –considered clean wounds that require local wound care and healing by secondary intention.
7. Animal bites – debride, irrigate, and close primarily or leave open, depending upon anatomic location, time since bite, etc.
    a. Augmentin is typically a mainstay of antibiotic prophylaxis.
    b. Consider rabies vaccine, if necessary.
8. Wounds of face
    a. Largely develop as result of trauma
    b. Important to first obtain a thorough trauma workup and rule out any intracranial injury, airway issues, or other intra-thoracic or abdominal injury.
    c. The face has reliable and excellent vascular supply, allowing for greater window of opportunity for delayed wound closure
    d. Consider serial examination and delayed closure to evaluate extent of necrotic tissue burden before definitive debridement, particularly if “questionably viable” tissue is in the wound bed.
    e. Reestablishment of symmetry: Carefully align anatomic landmarks such as vermilion border, ala, eyebrow, helical rim
9. Special Wounds
    a. Amputation of parts
        i. Place amputated part in saline soaked gauze in a plastic bag and place the bag on ice. Avoid direct contact with ice to prevent thermal injury.
        ii. Ischemia times for replantation are 12 hours of warm and 24 hours of cold ischemia for digits, and 6 hours of warm and 12 hours of cold ischemia for major replants of upper and lower extremity
    b. Cheek injury - may require exploration for parotid duct or facial nerve injury
    c. Intraoral injuries - tongue, cheek, palate, and lip wounds require approximation with absorbable suture
    d. Eyelids - align grey line and close in layers - consider temporary tarsorrhaphy
    e. Ear injuries
        i. Hematoma requires incision and drainage and well-molded dressing to prevent cauliflower ear deformity

ii. Through-and-through laceration requires 3-layer closure including cartilage
iii. Tapered, noncutting needles are indicated for cartilage repair
iv. Avoid oversuturing
v. May require bolster dressing afterwards to stabilize tissues and avoid hematoma
vi. Large composite defects must be approached in staged fashion

V. MANAGEMENT OF THE "CONTAMINATED" WOUND

A. Guidelines for management of contaminated acute wounds
   1. Majority of civilian traumatic wounds may be closed primarily after adequate debridement
   2. Sharp debridement followed by copious irrigation
   3. Consider healing by secondary intention if:
      a. Heavy bacterial inoculum
      b. Long time lapse since initial injury
      c. Crushed or ischemic tissue - severe contused avulsion injury
      d. Prolonged steroid use
   4. Antibiotics - systemic antibiotics are only of use if a therapeutic tissue level can be reached within four hours of injury or debridement
   5. Wound closure
      a. Buried deep dermal sutures should be used to keep wound edge tension to a minimum. Limit the amount of foreign material in wound as much as possible.
      b. Monofilament sutures less prone to infection
      c. With regard to deep open abdominal wounds, loss of domain can occur when muscle, fascia, or skin necrose or retract, allowing extrusion of viscera
         i. Wound closure attempts to recreate lost domain and reestablish function of abdominal wall
         ii. If in doubt, it is almost always safer to delay closure and consider scar revision at a future date
B. Guidelines for management of contaminated chronic wounds
   1. Debridement and irrigation, may require serial debridement to establish wound stability
   2. Systemic antibiotics of little use, unless patient demonstrates systemic signs of infection
   3. Topical antimicrobial creams - silver sulfadiazine and mafenide acetate
   4. Biological dressings (allograft, xenograft, etc.)
   5. Integra™ (Integra LifeSciences Corporation):
      a. Bilayer wound matrix: superficial layer is a semi-permeable silicone membrane that mimics epidermis, deep layer is a collagen-GAG matrix that mimics dermal layer.
      b. The silicone layer is peeled off after incorporation of deep layer.

c. Useful for wound coverage over devascularized wound bed with limited immediate reconstructive options

6. Final closure
   a. With a delayed flap, skin graft, or flap
   b. Convert the chronic contaminated wound to an acute clean wound by decreasing the bacterial count (debridement)
   c. Quantitative cultures may help guide management with regard to determining appropriateness for definitive closure

VI. WOUND DRESSINGS

Dressings serve to protect the wound from trauma and to provide an ideal environment for healing

A. Antibacterial ointments
   1. Bacitracin, Bacitracin/Neomycin/Polymyxin B, Mupirocin
      a. Provide moist environment conducive to epithelialization. Beware of secondary inflammatory reaction from antibiotic ointment that may mimic infection
      b. Mupirocin effective against MRSA
   2. Silver sulfadiazine and mafenide acetate
      a. Useful for burns
      b. Antibacterial activity penetrates eschar
      c. Mafenide has better penetration of cartilage
      d. Prolonged use of mafenide may promote fungal overgrowth
B. Splinting and casting
   1. Immobilization decreases shear forces on wounds and may help to promote wound healing
   2. Avoid splint for extended period of time to avoid joint stiffness
C. Pressure Dressings
   1. May be useful to obliterate "dead space" or to prevent seroma/hematoma
   2. Do not compress flaps too tightly, may risk compromising vascular supply

VII. NEGATIVE PRESSURE WOUND THERAPY (NPWT)

Beneficial tool for large wounds or contaminated wounds not amenable to primary closure

A. Technique includes application of foam sponge or gauze covered with adhesive dressing applied to vacuum device that provides constant sub-atmospheric pressure (-50 to -175mmHg)
   1. Should not be placed in direct contact with blood vessels or other fragile structures, infected or necrotic wounds, or on denuded bone.

2. NPWT may be placed over bilayer matrices (e.g. Integra™, Integra LifeSciences Corporation) to promote ingrowth of granulation tissue and development of a vascularized wound bed.
3. Dressing should be changed every 48-72 hours to assess wound progress and viability of tissue

B. Mechanism of action
   1. Maintains moist wound environment and reduces edema
   2. Promotes local wound blood flow and angiogenesis, reduces presence of inflammatory mediators, and speeds overall collagen synthesis and rate of wound closure by offloading mechanical tension on wound

C. Disadvantages: Cost of device, pain or discomfort with dressing changes and peri-wound irritation secondary to adhesive tape

D. Advantages: Can be used as adjunct dressing to serve as bolster for skin grafts and provide exudative management for draining wounds. Wound care regimen is less frequent for patients, making NPWT ideal for more cumbersome or extensive wounds that would otherwise require multiple daily dressing changes.

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