CHAPTER 1

WOUNDS

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 accidental following trauma. Immediately following wounding, the healing process begins.

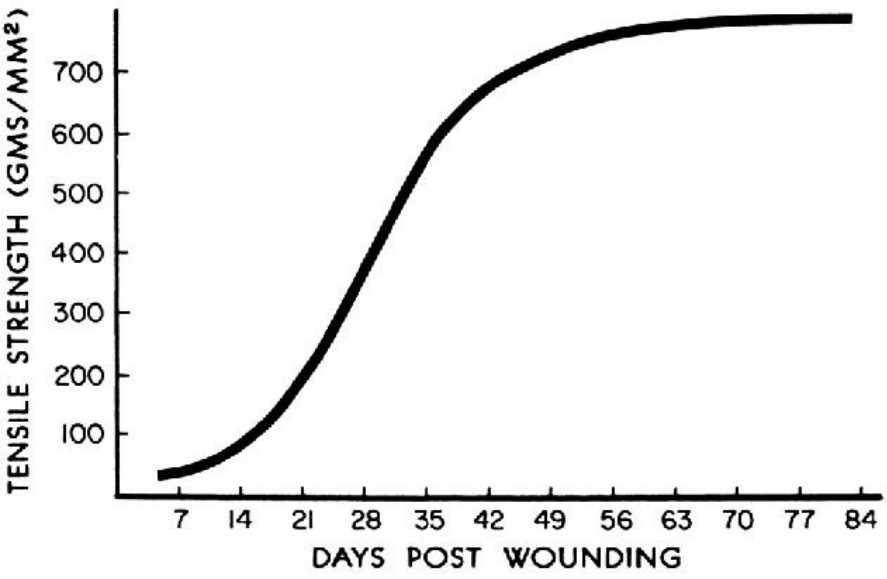
I. STAGES OR PHASES OF WOUND HEALING

Regardless of type of wound healing, stages or phases are the same except that the time required for each stage depends on the type of healing and other local factors that may influence wound closure (foreign body, infection, etc).

A. *Substrate* phase (inflammatory, lag or exudative stage or phase - days 1-4)
   1. *Symptoms* and signs of inflammation
      a. Redness(*rubor*), heat(*calor*), swelling(*tumor*), pain(*tumor*), and loss of function
   2. Physiology of inflammation
      a. Leukocyte margination, sticking, emigration through vessel walls
      b. Venule dilation and lymphatic blockade
      c. Neutrophil chemotaxis and phagocytosis
   3. Removal of clot, debris, bacteria, and other impediments of wound healing
   4. Lasts finite length of time (approximately four days) in primary intention healing
   5. Continues until wound is closed (unspecified time) in secondary and tertiary intention healing

B. Proliferative phase (collagen and fibroblastic stage or phase - approximately days 4-42)
   1. Synthesis of collagen tissue from fibroblasts
   2. Increased rate of collagen synthesis for 42-60 days
   3. Rapid gain of tensile strength in the wound (see Fig. 1-1)

C. Remodeling phase (maturation stage or phase - from approximately three weeks onward)
   1. Maturation by intermolecular cross-linking of collagen leads to flattening of scar
   2. Requires approximately 9-12 months in an adult - longer in children (Thus scar revisions may be delayed a year or longer after injury to ensure remodeling is complete)
   3. Dynamic, ongoing
   4. Tensile strength of a healed scar will peak at approximately 60 days post-injury and achieve up to 80% of unwounded skin



(Fig. 1-1)

II. WOUND CLOSURE

A. Primary healing (by primary intention) - wound closure by direct approximation, pedicle flap or skin graft
   1. Debridement of non-viable tissue and irrigation of the wound can minimize inflammation which will facilitate the healing process
   2. Dermis should be accurately approximated with sutures and is the strength layer of the wound repair (see chart at end of chapter) or skin glue if the wound is limited to partial thickness depth (i.e., cyanocrylate or histoacryl products)
   3. Scar may be red, raised, pruritic, and angry-looking at peak of collagen synthesis
   4. Thinning, flattening and blanching of scar occurs over approximately 9-12 months in adults, as collagen maturation occurs (may take longer in children)
   5. Final result of scar depends largely on how the dermis was approximated and can be influenced by tension of the closure, location and presence or absence of complicating environmental factors

B. Spontaneous healing (by secondary intention) - wound left open to heal spontaneously - maintained in inflammatory phase until wound closed
   1. Spontaneous wound closure depends on contraction and epithelialization
   2. Contraction results from centripetal force in wound margin probably provided by myofibroblasts
   3. Epithelialization proceeds from wound margins towards center at 1 mm/day
   4. Although contraction (the process of contracting) is normal in wound healing, one must beware of contracture (an end result - may be caused by contraction of scar and is a pathological deformity)
   5. Secondary healing beneficial in some wounds, e.g. perineum, heavily contaminated wounds, scalp

C. Tertiary healing (by tertiary intention) - delayed wound closure after several days

1. Distinguishing feature of this type of healing is the intentional interruption of healing begun as secondary intention
2. Can occur any time after granulation tissue has formed in wound
3. Delayed closure should be performed when wound is not infected (usually 105 or fewer bacteria/gram of tissue on quantitative culture except with beta-STREP)

III. FACTORS INFLUENCING WOUND HEALING

A. Local factors most important because we can control them
   1. Tissue trauma - must be kept at a minimum
   2. Hematoma - associated with higher infection rate
   3. Blood supply
   4. Temperature
   5. Infection
   6. Technique and suture materials - only important when factors 1-5 have been controlled
B. General factors - cannot be readily controlled by surgeon; systemic effects of steroids, nutrition, chemotherapy, chronic illness, etc., contribute to wound healing

IV. MANAGEMENT OF THE CLEAN WOUND

A. Goal - obtain a closed wound as soon as possible to prevent infection, fibrosis and secondary deformity
B. General principles
   1. Immunization - use American College of Surgeons Committee on Trauma recommendation for tetanus immunization
   2. If necessary, use pre-anesthetic medication to reduce anxiety while adhering to proper monitoring and safety measures to prevent medication related complications
   3. Local anesthesia - use amide ester (Lidocaine) with epinephrine unless contraindicated, e.g. tip of penis, fingetip
   4. Tourniquet to provide bloodless field in extremities
   5. Cleansing of surrounding skin - do NOT use strong antiseptic in the wound itself that may interfere with re-epithelithiation or collagen synthesis
   6. Debridement
      a. Remove clot and debris, necrotic tissue
      b. Copious irrigation good adjunct to sharp debridement
   7. Closure – use atraumatic technique to approximate dermis. Consider undermining of wound edges to relieve tension
   8. Dressing - must provide absorption, protection, immobilization, even compression, and be aesthetically acceptable
C. Types of wounds and their treatment
   1. Abrasion - cleanse to remove foreign material
      a. Consider scrub brush or dermabrasion to remove dirt buried in dermis to prevent traumatic tattoos (permanent discoloration due to buried dirt beneath new skin surface) - needs to be accomplished within 24 hours of injury
   2. Contusion - consider need to evacuate hematoma if collection is present or if pressure of hematoma is compromising surrounding tissue
      a. Early - minimize by cooling with ice (24-48 hours)

b. Later - warmth to speed absorption of blood

3. Laceration - trim wound edges if necessary (ragged, contused) and suture
4. Avulsion
   a. Partial (creates a flap) - revise and suture if viable
   b. Total - do not replace totally avulsed tissue except as a skin graft after fat is removed
5. Puncture wound - evaluate underlying damage, possibly explore wound for foreign body, etc.
6. Animal bites - debride and close primarily or leave open, depending upon anatomic location, time since bite, etc. Use antibiotics

D. Wounds of face
   1. Important to use careful technique
      a. Urgency should not override judgment
      b. There is a longer "period of grace" during which the wound may be closed since blood supply to face is excellent
      c. Do not forget about other possible injuries (chest, abdomen, extremities). Very rare for patient to die from facial lacerations alone
   2. Facial lacerations of secondary importance to airway problems, hemorrhage or intracranial injury
   3. Beware of overaggressive debridement of questionably viable tissue. May consider serial exams and closure to determine viability of tissue
   4. Isolate cavities from each other by suturing linings, such as oral and nasal mucosa
   5. Use anatomic landmarks to advantage, e.g. alignment of vermilion border, nostril sill, eyebrow, helical rim

E. Wounds of the upper extremity (See Chapter 6)

F. Special Wounds
   1. Amputation of parts
      a. Attempt replacement if within six hours of injury
      b. Place amputated part in saline soaked gauze in a plastic bag and the bag in ice. Protect tissue from direct contact with ice to prevent thermal injury
   2. Cheek injury - examine for parotid duct and/or facial nerve injury
   3. Intraoral injuries - tongue, cheek, palate, and lip wounds require suturing
   4. Eyelids - align grey line and close in layers - consider temporary tarrsoraphy
   5. Ear injuries
      a. Hematoma - incision and drainage of hematoma and well-molded dressing to prevent cauliflower ear deformity
      b. Through-and-through laceration requires 3 layer closure including cartilage
   6. Animal bites - debridement, irrigation, antibiotics, and possible wound closure. Be particularly careful of cat bites which can infect with a very small puncture wound

V. MANAGEMENT OF THE "CONTAMINATED" WOUND

A. Guidelines for management of contaminated acute wounds
   1. Majority of civilian traumatic wounds can be closed primarily after adequate debridement
      a. Adequate debridement
         i. Mechanical/sharp or chemical/enzymatic (eg. Collagenase, Panafil®)

ii. Irrigation - copious pulsatile lavage
b. Exceptions (may opt to leave wound open)
i. Heavy bacterial inoculum (human bites)
ii. Long time lapse since wounding (relative)
iii. Crushed or ischemic tissue - severe contused avulsion injury
iv. Sustained high-level steroid ingestion (some animal studies indicate that oral administration of Vitamin A (retinoic acid) can mitigate some of the effects of steroids on wound healing).

2. Antibiotics - Systemic antibiotics are only of use if a therapeutic tissue level can be reached within four hours of wounding or debridement
3. Wound closure
a. Buried sutures should be used to keep wound edge tension to a minimum; however, each suture is a foreign body which increases the chance of infection (use least number of sutures possible to bring wound together without tension)
b. Skin sutures of monofilament material are less apt to become infected
c. Porous tape closure may be used for some wounds
4. Follow up - contaminated traumatic wounds should be checked for infection within 48 hours after closure
5. If doubt exists, it is always safer to delay closure (revision can be done later)

B. Guidelines for management of contaminated chronic wounds
1. Examples - wounds greater than 24 hours old
a. Common ingredient - granulation tissue
2. Debridement as important as in an acute wound
a. Excision (scalpel, scissors)
b. Frequent dressing changes
c. Enzymatic - seldom indicated
3. Systemic antibiotics of little use
4. Topical antibacterial creams - silver sulfadiazine (Silvadene¨) and mafenide acetate (Sulfamylon¨)
a. Continual surface contact
b. Good penetrating ability
c. Decrease bacterial counts of wounds
5. Biological dressings (allograft, xenograft, some synthetic dressings) debride wound, decrease pain.
6. Final closure
a. With a delayed flap, skin graft or flap
b. Convert the chronic contaminated wound bacteriologically to an acute clean wound by decreasing the bacterial count (debridement)

VI. WOUND DRESSINGS

A. Protect the wound from trauma
B. Provide environment for healing
C. Antibacterial medications
1. Bacitracin® and Neosporin®
a. Provide moist environment conducive to epithelialization. Beware of secondary inflammatory reaction from antibiotic cream that may mimic infection

2. Silver sulfadiazine (Silvadene®) and mafenide acetate (Sulfamylon®)
    a. Useful for burns or other wounds with an eschar
    b. Antibacterial activity penetrates eschar

D. Splinting and casting
    1. For immobilization to promote healing
    2. Do not splint too long - may promote joint stiffness

E. Pressure Dressings
    1. May be useful to prevent "dead space" (potential space in wound) or to prevent seroma/hematoma
    2. Do not compress flaps tightly

F. Do not leave dressing on too long (<48 hours) before changing

VII. NEGATIVE PRESSURE WOUND THERAPY (NPWT)

Relatively new dressing that may be beneficial tool for large wounds or contaminated wounds that are not amenable to primary closure (V.A.C.™ therapy –KCI, San Antonio, TX, Chariker-Jeter™ Smith and Nephew, PLC, London, UK)

A. Technique includes application of foam sponge or gauze covered with adhesive dressing applied to vacuum device that provides subatmospheric pressure (-50 to -175mmHg)
    1. Should not be placed in direct contact with blood vessels or other fragile structures. Also should not be used in grossly purulent or necrotic wounds
    2. Dressing should be changed every 48-72 hours to assess wound progress and viability of tissue

B. Mechanism of Action
    1. Maintains a moist wound environment and reduces edema
    2. Increases local wound blood flow, reduces presence of inflammatory mediators, and may speed overall collagen synthesis and rate of wound closure

C. Disadvantages include cost of device, pain with dressing changes and peri-wound irritation secondary to adhesive drape

D. Can be used as adjunct dressing to serve as bolster for skin grafts, and provide exudative management for draining wounds

ETHICON* Synthetic Absorbable Sutures					
SUTURE & COMPOSITION	***COLOR & TYPE***	***BSR***	***ABSORPTION RATE***	***FREQUENT USES***	***MAIN BENEFIT***
Coated **VICRYL RAPIDE*** (polyglactin 910) suture	Undyed Braided	50% at 5 days 0% at 10 to 14 days	Essentially complete by 42 days	**Skin and Mucosa:** - Episotomy repair - Lacerations under casts - Mucosa in oral cavity - Skin repairs where rapid absorption may be beneficial, excluding joints and high stress areas	Patient comfort No suture removal
MONOCRYL* (poliglecaprone 25) suture	Undyed/Dyed (violet) Monofilament	**Dyed:** 60 to 70% at 7 days 30 to 40% at 14 days **Undyed:** 50 to 60% at 7 days 20 to 30% at 14 days	Essentially complete between 91 and 119 days	**Soft Tissue Approximation:** - Ligation - Skin Repairs - Bowel - Peritoneum - Uterus - Vaginal Cuff	Unprecedented monofilament pliability Smooth tissue passage
Coated **VICRYL** (polyglactin 910) suture	Undyed/Dyed (violet) Braided	75% at 14 days 50% at 21 days† 40% at 21 days‡	Essentially complete between 56 and 70 days	**Soft Tissue Approximation:** - Ligation - General Closure - Ophthalmic Surgery - Orthopaedic Surgery - Bowel	Strength, preferred performance and handling Knot security
PDS* II (polydioxanone) suture	Undyed/Dyed (violet) Monofilament	70% at 14 days 50% at 28 days 25% at 42 days	Essentially complete within 6 months	**Soft Tissue Approximation:** - Fascia Closure - Orthopaedic Surgery - Blood Vessel Anatomoses - Pediatric Cardiovascular and Ophthalmic procedures - Patients with compromised wound healing conditions	Longest lasting absorbable monofilament wound support Outstanding pliability

*Trademark † Sizes 6/0 and larger ‡ Sizes 7/0 and larger

CHAPTER 1 – BIBLIOGRAPHY

WOUNDS

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