Basic Techniques

Wound Healing

Phases of Wound Healing (Pitzer & Patel 2011, Leach 2001) (see Table 2.1)

1. INFLAMMATORY (up to 7 days after injury)
   (a) Endothelial injury starts clotting cascade
      • Exposes: Collagen, laminin, and fibronectin
      • Clot: Platelets and fibrin
      • Releases: Histamine, proteases, prostaglandins, serotonin
   (b) Vasoconstriction priority (thromboxane A2—lasts 5–10 min)
   (c) Vasodilation from histamine, increased vessel permeability (edema) for 48–72 h
   (d) Key cellular response begins:
      • Granulocytes arrive within 6 h
      • Macrophages dominate by 2–4 days
        – Release TGF-B, FGF, remodeling factors
   (e) End result: cells ready for proliferation in wound bed
   (f) Wound strength: 5–10% of normal tissue
   (g) To promote optimal healing: use aseptic technique, copiously irrigate with saline (10–15 psi ideal for cleaning without causing damage/seeding), ± antibiotics (i.e., 50,000 U of bacitracin)

2. PROLIFERATIVE (1–21 days after injury)
   (a) Re-epithelialization (1–5 days)
      • Creates protective barrier
      • Begins at hair follicles/adnexa/sebaceous glands
      • Rapid when primarily closed
        – Promoted by moist environment
      • Prolonged (3–5 days) when healing secondarily or over poor vasculature
   (b) Neovascularization (3–4 days after injury)
      • Granulation tissue produced by activity of macrophages
        – Scaffold holding vessels, matrix of nutrients, cells, fibronectin/collagen
      • Present until epithelialization is complete
   (c) Collagen Synthesis
      • Type III collagen predominates early → type I collagen during maturation (see below)
**Table 2.1** Phases and characteristics of wound healing

<table>
<thead>
<tr>
<th>Wound healing phases</th>
<th>Time after injury</th>
<th>Key cellular components</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inflammatory</td>
<td>&lt;7 days</td>
<td>Platelets, granulocytes, macrophages</td>
<td>5–10 %</td>
</tr>
<tr>
<td>Proliferative</td>
<td>1 day–3 weeks</td>
<td>Fibroblasts</td>
<td>50 %</td>
</tr>
<tr>
<td>Maturation</td>
<td>3 weeks–1 year</td>
<td>Myofibroblasts</td>
<td>80 %</td>
</tr>
</tbody>
</table>

(d) Contracture (1–3 weeks after injury)
- Mediated by **myofibroblasts**
- Maximum at 12–15 days after injury, occurs at 0.7 mm/day
- Worse if left open or inflamed
  - Contraction lessened by skin grafts (still contract by 20 % depending on type of skin graft)

(e) Key cellular components:
- **Fibroblasts**—migrate to wound bed, direct collage, elastin, GAG formation, differentiate into myofibroblasts

(f) End result: **disorganized collagen, relatively hypertrophied, erythematous scar**

(g) Wound strength: **increases slowly for 2 weeks, linearly for 4 weeks, 50 % of final wound strength (40 % of normal skin) at 6 weeks**

(h) To promote optimal healing: **close primarily if possible/applicable, optimize nutritional status (collagen cross-linking), keep wound clean and moist, use occlusive/semi-occlusive or silicone dressings. Mederma (onion extract) showed no visible benefit in humans in RCTs.**

3. REMODELING/MATURATION
   (3 weeks–12 months after injury)
   (a) **Collagen remodeling** (continue transition to type I collagen)—increases strength
      - Disarrayed fibers are remodeled, becoming **parallel, organized woven**
   (b) Decreased vascularity—resolves erythema
   (c) Key cellular components:
      - **Myofibroblasts**—mediate contraction, then die (except in keloids)
   (d) End result: **fully contracted, avascular scar**

(e) Wound strength: **80 % of normal skin**

(f) To promote optimal healing: **pressure dressings, massage, sun avoidance**, reducing inflammation (steroid injections into scar only—not surrounding tissue)

**Traumatic Wounds (see chapter 2.6 for more detail)**

- Evaluation—depth of wound: layers, structures involved determine reconstructive approach
  - Determine if there is functional or sensory deficit before application of local anesthetic
  - Facial nerve exploration if the injury is lateral to lateral canthus
  - Parotid duct injury/exploration for lateral cheek

- **Tetanus status**
  - Booster (**tetanus toxoid**) every 10 years
  - **Contaminated wounds**, deep punctures—tetanus booster within 5 years
  - Less than two prior doses of toxoid, needs tetanus immunoglobulin

- Post-injury use antibiotics:
  - Immunocompromised
  - Rheumatic heart disease or implants
  - Contaminated wounds (bites)

- **Bites**
  - Dogs and cats—cover *staphylococci, streptococci*, anaerobes, and *Pasteurella multocida* species for 5 days (see Table 2.2)
    - Augmentin BID or
    - Clindamycin with Cipro or
    - Bactrim
  - Monkeys—treat with antivirals also
  - Rabies (unprovoked attack, test the animal)
Surgical Techniques

- Infection prevention (aseptic technique) and control (wound cleanliness—see Table 2.3)
- WHO guidelines for antibiotic use:
  - Within 60 min but prior to incision for Ancef, Unasyn, clindamycin
  - Within 120 min but prior to incision for vancomycin and fluoroquinolones
  - Re-dose when surgery exceeds half-life of drug or if significant bleeding
- Place incisions in relaxed skin tension lines (see below)
- Debride necrotic tissue and remove foreign bodies (including unnecessary sutures)
- Atraumatic tissue handling (do not crush)
- Use sharp anatomic dissection of tissue and freshen wound edges
- Obliterate dead space (prevents seroma/hematoma formation)
- Avoid tension on epithelial wound edges
  - Undermining up to 4 cm from wound edge can relax tension (more doesn’t help)
- Trichophytic incisions
  - Cut between follicles on a bias (so hair grows through the incision)
- Suture choices (see Tables 2.4 and 2.5)
  - Smallest needle and suture caliber that is strong enough to resist deformation
  - Least inflammatory
  - Remove permanent sutures in 5–7 days

Tissue Glue
- Three layers recommended by most manufacturers
- Dermabond (Octylcyanoacrylate) is strongest among currently available
- Equally as effective to sutures in lacerations parallel to RSTLs
- Superior to sutures in lacerations perpendicular to RSTLs
- Not good for areas of high motion

Table 2.2 Antibiotic therapy in animal bites

<table>
<thead>
<tr>
<th>Animal</th>
<th>Antibiotic Therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dog</td>
<td>“Dog”-mentin</td>
</tr>
<tr>
<td>Cat</td>
<td>Clinda &amp; Cipro</td>
</tr>
</tbody>
</table>

Table 2.3 Surgical wound classification—ACS-NSQIP

<table>
<thead>
<tr>
<th>Wound class</th>
<th>Class I—clean</th>
<th>Class II—clean contaminated</th>
<th>Class III—contaminated</th>
<th>Class IV—infected/dirty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Example</td>
<td>Uninfected, incision in skin after surgical prep</td>
<td>Incision in the respiratory, alimentary, or urinary systems</td>
<td>Open or fresh wounds, surgical wound with gross spillage</td>
<td>Old wounds, evidence of infection in wound</td>
</tr>
<tr>
<td>Infection rate</td>
<td>1–5 %</td>
<td>3–11 %</td>
<td>8–17 %</td>
<td>12–27 %</td>
</tr>
</tbody>
</table>

Table 2.4 Absorbable suture types

<table>
<thead>
<tr>
<th>Suture Type</th>
<th>Absorbable suture types and characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monofilaments:</td>
<td>Absorption 50 % strength</td>
</tr>
<tr>
<td>Fast gut</td>
<td>10–20 days</td>
</tr>
<tr>
<td>Plain gut</td>
<td>30–60 days</td>
</tr>
<tr>
<td>Chromic gut</td>
<td>70–90 days</td>
</tr>
<tr>
<td>Poliglecaprone (Monocryl)</td>
<td>3–4 months</td>
</tr>
<tr>
<td>Polydioxanone (PDS)</td>
<td>6–8 months</td>
</tr>
<tr>
<td>Braided:</td>
<td>Polyglactin 910 (Vicryl) 2 months 3 weeks</td>
</tr>
</tbody>
</table>

Table 2.5 Non-absorbable suture types

<table>
<thead>
<tr>
<th>Non-absorbable suture types and uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monofilaments:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Braided:</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
• Secondary healing in <2 cm concave areas is acceptable (van der Eerden 2008)
• Dermabrasion at 4–8 weeks after injury improves scar appearance

Histology

• Normal Skin Histology
  – Layers of the skin (see Fig. 2.1)
  – Collagen—80–90 % type I collagen
  – Scalp—thicker stratum corneum
• Blood supply
  – Choke vessels under the dermis—subdermal plexus
  – Capillary network under epidermis
• Skin cancer histology
  – Sites of origination
  – BCC—basal cell layer
  – SCC—keratinocytes
  – Melanoma—melanocytes
• Keloid vs. hypertrophic scars
  – Hypertrophic scars—more type III collagen
  – Keloids—increased TGF-B expression, expand beyond the boundary of the original injury, failure of myofibroblast apoptosis

• Fitzpatrick skin types (see Table 2.6)
  – Classification of skin response to UV exposure

Surgical Anatomy

• Embryology (see Table 2.7)
• Facial proportions
  – Vertically divided in 1/3s by:
    Trichion
    Glabella
    Subnasale
    Menton
  – Horizontally divided in 1/5s by:
    Edge of helix
    Lateral canthus
    Medial canthus

Table 2.6 Fitzpatrick scale

<table>
<thead>
<tr>
<th></th>
<th>Fitzpatrick scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Always burns</td>
</tr>
<tr>
<td></td>
<td>Pale, fair, freckles</td>
</tr>
<tr>
<td>II</td>
<td>Usually burns, sometimes tans</td>
</tr>
<tr>
<td></td>
<td>Fair</td>
</tr>
<tr>
<td>III</td>
<td>May burn, usually tans</td>
</tr>
<tr>
<td></td>
<td>Light brown</td>
</tr>
<tr>
<td>IV</td>
<td>Rarely burns, always tans</td>
</tr>
<tr>
<td></td>
<td>Olive</td>
</tr>
<tr>
<td>V</td>
<td>Moderate constitutional pigmentation</td>
</tr>
<tr>
<td></td>
<td>Brown</td>
</tr>
<tr>
<td>VI</td>
<td>Marked constitutional pigmentation</td>
</tr>
<tr>
<td></td>
<td>Black</td>
</tr>
</tbody>
</table>

Fig. 2.1 Cross section of skin (left) with cellular component of epidermis (right)
Table 2.7  Embryologic arches and derivatives

<table>
<thead>
<tr>
<th>Arch</th>
<th>Connective tissue</th>
<th>Artery</th>
<th>Muscles</th>
<th>Nerves</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>Maxilla, mandible, zygoma, malleus, incus</td>
<td>Maxillary</td>
<td>Muscles of mastication, mylohyoid, ant digastric, tensor tympani, tensor veli palatini</td>
<td>V3</td>
</tr>
<tr>
<td>2nd</td>
<td>Stapes, styloid, hyoid (lesser horn)</td>
<td>Hyoid, stapedia</td>
<td>Facial expression, post digastric, stapedius, stylohyoid</td>
<td>VII</td>
</tr>
<tr>
<td>3rd</td>
<td>Hyoid (greater horn)</td>
<td>Common carotid</td>
<td>Stylopharyngeus</td>
<td>IX</td>
</tr>
<tr>
<td>4th</td>
<td>Thyroid cartilage</td>
<td>Aortic arch, right subclav</td>
<td>Constrictors, cricothyroid, levator veli palatini</td>
<td>X (superior branch)</td>
</tr>
<tr>
<td>6th</td>
<td>Cricoid cartilage</td>
<td>Pulmonary arteries, ductus arteriosus</td>
<td>Intrinsic laryngeal muscles</td>
<td>X (recurrent)</td>
</tr>
</tbody>
</table>

Fig. 2.2  Superficial landmarks (profile view)

- Divine proportions (Golden Rule)
  \[ \Phi = 1.618 \ldots \]
  Facial height/facial width
  Facial height (trichion to midpupillary line to menton)
  Several others (controversial)
- Superficial landmarks (see Fig. 2.2)
  - Skin-retaining ligaments of the face:
    - Mandibular
    - Masseteric
    - Zygomatic—McGregor’s patch
Platysmal-auricular
Obicularis

- Facial skeleton
  - Beams (4)
  - Frontal bar
  - Infraorbital/Zygomatic process
  - Maxillary alveolus
  - Mandible
  - Buttresses (4)
    - Nasomaxillary
      - Zygomaticomaxillary—capable of greatest load bearing
      - Pterygomaxillary
      - Nasal septum

- Cutaneous innervation (see Fig. 2.3)
  - Anterior ½ from trigeminal nerves
  - Posterior ½ from cervical nerves

- Motor nerves
  - Facial nerve (see Fig. 2.4)
    - Main trunk—five ways to identify it (see Table 2.8)
    - Extracranial course—deep to posterior belly of digastric
    - Pes anserinus—temporofacial and cervico-facial branches
      - Temporofacial—zygomatic and frontal
      - Cervicofacial—buccal, marginal, cervical
  - Motor nerve to masseter
    - Subzygomatic triangle
      - Frontal branch, zygoma, TMJ
      - 3 cm anterior to tragus
      - 1 cm inferior to zygomatic arch
      - 1.5 cm deep to SMAS

A - Ophthalmic (V1) area
B - Maxillary (V2) area
C - Mandibular (V3) area
D - Superficial cervical plexus
E - Cervical nerves (posterior divisions)

Fig. 2.3 Pattern of cutaneous facial innervation
SMAS
- Continuous with platysmal
- Continuous with superficial temporal fascia
- Invests in nasolabial, peri-ocular, peri-oral musculature

Scalp
- Layers—skin, connective tissue, aponeurosis (galeal), loose connective tissue, pericranium
  Galeal aponeurosis invests the frontalis and occipitalis muscles
- Temporalis fascia
  Superficial layer
  Deep layers—superficial and deep surround temporalis muscle
  **Frontal branch of VII runs deep to the superficial layer of deep temporal fascia**

Muscles of facial expression (see diagram below) (see Fig. 2.5)

---

**Table 2.8 Methods of finding the facial nerve**

<table>
<thead>
<tr>
<th>Identifying the facial nerve:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 1 cm deep and 1 cm inferior to tragal pointer</td>
</tr>
<tr>
<td>2. Drill vertical portion in the mastoid to the stylomastoid foramen</td>
</tr>
<tr>
<td>3. Peripheral branch, retrograde dissection</td>
</tr>
<tr>
<td>4. Follow the stylomastoid suture line</td>
</tr>
<tr>
<td>5. Deep to posterior belly of digastic muscle attachment to digastic groove</td>
</tr>
</tbody>
</table>

**Fig. 2.4 Landmarks to finding the facial nerve**
- All innervated from deep surface except “MLB”
  - **Mentalis**
  - **Levator anguli oris**
  - **Buccinator**
  - Orbicularis oculi parts:
    - Pretarsal
    - Preseptal (Palpebral)
    - Orbital
- Nasal musculature
  - Nasalis dilator—flares lower lateral cartilages
  - Nasalis transverse—compresses the nasal wall
  - Depressor septi (depressest tip)
  - Levator labii superioris alaeque nasi (flares—produces “gummy smile”—runs in the alar crease)
  - Procerus (elevates tip)
- Ear wiggles:
  - Posterior, superior, and anterior auricular muscles
  - Rhytides
- Glabella
Vertical rhytides—corrugator (looks concerned)
Horizontal rhytides—procerus (looks pissed!)
- Crow’s feet—orbicularis oculi
- Nasolabial and melolabial—investment of SMAS fibers to skin, orbicularis oris

• Orbital anatomy (see Table 2.9, Figs. 2.6, 2.7, 2.8, 2.9, and 2.10)
  - Medial wall structures (see Table 2.9)
  - Peak of eyebrow should be at the lateral limbus
  - Tarsal show (Caucasians): 7–8 mm

Table 2.9 Distance to critical structures along the medial orbital wall
<table>
<thead>
<tr>
<th>Medial orbital wall structures</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior lacrimal crest to:</td>
<td></td>
</tr>
<tr>
<td>Anterior ethmoid art: 24 mm</td>
<td></td>
</tr>
<tr>
<td>Posterior ethmoid art: +12 mm</td>
<td></td>
</tr>
<tr>
<td>Optic nerve: +6 mm</td>
<td></td>
</tr>
</tbody>
</table>

- Brow to supratarsal crease: 10–11 mm
- Superior tarsal plate height: 8–9 mm
- Inferior tarsal plate height: 4–5 mm
- **Asian eyelid:** lower (or absent) insertion of the levator aponeurosis to the skin, allow ptosis of orbital fat down to lid margin

• Nose
  - **Nasal tip innervated by V1**
  - Vascular supply:
    - External carotid
      - (a) IMA → greater, lesser palatine
      - (b) IMA → sphenopalatine → posterior septal and lateral nasal branches
      - (c) Facial artery → superior labial, angular, lateral nasal
    - Internal carotid
      - (a) Anterior and posterior ethmoid, dorsal nasal

Fig. 2.6 Right orbital fissure contents
- **Mouth**
  - External landmarks
    - Philtrum
    - Modiolus
    - White roll
  - Musculature
    - Several parts to orbicularis oris
      - (a) Originate from buccinators, depressor septi, mentalis
      - (b) Philtrum overlies area of decussation
  - Labial artery runs between orbicularis oculi and mucosa at or inferior to the level of the vermilion border (see Fig. 2.11)
Mandible (see Fig. 2.12)
- Muscles and motions
  *Lateral pterygoid* (condyle/coronoid) **opens the jaw**
  Temporalis (coronoid), Masseter (angle), medial pterygoid (behind the mylohyoid groove, medial angle of mandible)—**close the jaw**

- Superficial neck
  - Great auricular nerve
  - External jugular (anterior to great auricular)

- Ear (see Figs. 2.13, 2.14, 2.15, and 2.16)
  - Vertical height ~6 cm; width: 3.5 cm
- Orientation: ~20° or “parallel to nasal dorsum” (usually less)
- Projects 20–30°, 2–3 cm from mastoid
- Blood supply from:
  - Posterior auricular
  - Superficial temporal
  - Posterior occipital
  - Deep auricular
- Cartilage framework

**Fig. 2.12** Muscles influencing jaw opening and closing

**Fig. 2.13** Facial landmarks of the ear and their derivatives (Hillocks of His numbering 1–6)

**Fig. 2.14** Cutaneous innervation of the ear

**Hillocks of His**
1–3 from first arch
4–6 from second arch

- Cutaneous innervation (see below)
Fig. 2.15 External landmarks of the ear

External Ear Landmarks:
1. Helix
2. Helical tubercle
3. Scaphoid fossa
4. Stem of antihelix
5. Superior crus
6. Inferior crus
7. Triangular fossa
8. Concha cymba
9. Concha cavum
10. Antitragus
11. Lobule
12. Intertragal incisura
13. Tragus
14. Anterior incisura
15. Otobasion inferioris
16. Cauda helicis- inferior edge of cartilage extending towards lobule

Fig. 2.16 Arterial supply to the head and neck. Illustration: Gray’s Anatomy © 1918 (public domain)
Arterial anatomy of the face (see Figs. 2.16 and 2.17, Table 2.10)

- External carotid branches (Some Angry Ladies Fight Off PMS)
  - Superior Thyroid
  - Ascending pharyngeal (posterior)
  - Lingual
  - Facial (“external maxillary” in old texts)
  - Occipital (posterior)
  - Posterior auricular (posterior)
  - Maxillary (“internal maxillary” in old texts)
  - Superficial temporal (terminal branch)

Additional Resources

Questions

1. What is the mechanism for wound contracture?
(a) Neutrophils
(b) Macrophages
(c) Myofibroblasts
(d) TGF-B

2. Why does edema impair wound healing?
(a) Dilution of growth factors
(b) Decreased pO₂
(c) Increased protein deposition
(d) All of the above

3. What is the difference between hypertrophic and keloid scars?


5. What muscles of facial expression are innervated from their superficial surface?
6. What is the structural difference between Asian and Caucasian eyelids?
7. How many orbital fat compartments are there?
8. How many limbs of the medial canthal tendon? What do they surround?
9. What does the gray line represent?
10. How many parts of the orbicularis oculi?
11. What angle does the ear project off the mastoid? What distance?
12. What nerve innervates the nasal tip?
13. What are the measurements and/or superficial landmarks for locating the supratrochlear artery?

**Answers**

1. (c) Myofibroblasts are fibroblasts with increased levels of actin, making them able to contract. This occurs in the remodeling phase of healing.
2. (d) Oxygen and nutrients can only reach wounds by diffusing from adjacent capillaries (2 cell widths). Edema increases this distance, and allows protein deposition impairing healing.
3. Hypertrophic scars do not extend beyond the boundary of the initial wound (keloids do extend into adjacent tissue). Both are hyperinflammatory responses. Predisposition to keloid scars may be genetic (AD transmission).
4. Beer bottle: class III (contaminated), bear attack: class III (contaminated), open SRP: class II (surgical incision in the aerodigestive tract)
5. MLB—mentalis, levator anguli oris, buccinator
6. Lower or lack of skin insertions of the levator aponeurosis allowing descent of preseptal orbital fat toward the lash line
7. 5 (lacrimal gland replaces the lateral/superior compartment)
8. Pretarsal orbicularis that is behind the lash line (called the muscle of Riolan)
9. 2 (anterior and posterior) surround the lacrimal sac
10. 3—orbital, pretarsal, and preseptal (together called the palpebral)
11. 20–30°; 20 mm
12. V1
13. 1.7–2.2 cm from midline, medial head of the brow