Agenda

• Noon – 12:45pm: Lecture

• 12:45pm – 1:00pm: Break

• 1:00pm – 2:00pm: Knot Tying Lab

• 2:00pm – 2:15pm: Break

• 2:15pm – 4:00pm: Suture Lab
Every wound is simply a disruption of the normal continuity of tissue.
Objectives

• Review general principles of wound healing and wound closure
• Review types of suture and needles
• Review commonly used surgical instruments and technique when suturing
• Provide a general overview of basic types of knot tying and suturing
Wound Healing

• Three phases of wound healing
  • Hemostasis and inflammation
  • Fibroplasia (proliferation and migration)
  • Maturation and remodeling
• Considerable overlap between phases
Wound Healing
Phase 1 – Hemostasis & Inflammation

- Vascular disruption → transient vasoconstriction → vasodilatation and increased capillary permeability (edema).
- Platelet aggregation, coagulation cascades, and influx of inflammatory cells.
  - Neutrophils, the first nucleated cells to arrive, initiate phagocytosis and antimicrobial defense.
  - By the 3rd or 4th day, macrophages dominate and play a central role in removing microbes and cellular debris.
Inflammatory response abates, and the fibroplastic phase peaks by the 5th day. After 5-7 days, fibroblasts predominate, and they begin to synthesize and secrete proteoglycans, collagen, and elastin. New capillaries develop. Epithelial cells proliferate and migrate. Gradual decrease in the size of the wound from wound healing and contraction.
Wound Healing

Phase 3 – Maturation (remodeling)

- Result of matrix synthesis and degradation
- Cross-linking of collagen (type III replaced by type I)
- Progressive increase in tensile strength
- For skin...
  - At 2 weeks, the wound is ~20% of its pre-wound strength
  - By 5 weeks, ~50%
  - By 10 weeks, ~80%
- Intestines may regain 100% of original strength within just 1 wk
- Scar flattens
- Remodeling and maturation of the scar continues for 1+ years.
Basic Principles of Wound Closure

- **Minimize bacterial contamination.**
  - Bacterial contamination can be reduced by irrigating the wound with large amounts of sterile saline under moderate pressure.

- **Remove foreign bodies & devitalized tissue.**

- **Achieve hemostasis.**

- **Close dead spaces to prevent infection and collection of fluid.**
  - May also help restore normal anatomic planes and prevent the creation of new ones.

- **Prevent future complications.**
  - May decrease chance of developing fistulas, infections, etc.

- **Better cosmetic result?**
BASIC TYPES OF WOUND CLOSURE
Wound Closure Basics

**Closure by Primary Intent**

- Wound closure immediately following the injury and prior to the formation of granulation tissue.
- In general, leads to faster healing and the best cosmetic result.
- Most patients presenting within 8 hours of injury can have the wound closed primarily.
- Simple and clean facial wounds, by virtue of the rich vascular supply to the face and the need for a good cosmetic result, can be closed primarily as late as 24 hours after the injury.
Wound Closure Basics

Closure by Secondary Intent

• Allowing wounds to heal on their own without surgical closure from inner layer to outer surface.
  • Granulation tissue forms, contains myofibroblasts which help close wound by contraction
  • Much slower than primary intention

• Wounds should be cleaned and dressed.

• In the setting of infection, excessive trauma, tissue loss, or imprecise approximation of tissue

• Certain wounds, such as small partial thickness avulsions and fingertip amputations, are best left to close by secondary intent.
Wound Closure Basics

Closure by Tertiary Intent

• Delayed primary closure = when two surfaces of granulation tissue are brought together.
• Typically treated with debridement first, then left open until gains sufficient resistance to infection.
• Patient returns in 3-4 days, after initial wound cleansing and dressing, for wound closure.
• Used for patients with wounds who present late (>24 hours) for care, contaminated crush wounds and mammalian bites when leaving the wound open would result in an unacceptable cosmetic result.
  • Used extensively in the military and trauma
Complications in Wound Closure

- Infection
- Fluid collection
  - Benign
  - Hematoma
- Scarring
  - Cosmetic
  - Hypertrophic
  - Keloids
- Dehiscence (wound disruption)
- Evisceration
  - EMERGENCY!
Patient Factors That Influence Wound Healing

- Age
- Hydration
- Nutritional status
- Obesity
- Autoimmune disease
- Comorbidities
  - Acute vs. chronic
  - Malignancy
- Infection/contamination
- Prior radiation
- Wound blood supply
- Wound location
Types of Operative Wounds

- **Clean**
  - 75% of operative wounds
  - Elective incisions made with no break in aseptic technique
  - Surgeon does not enter oropharyngeal cavity, respiratory, GI, or GU tracts
- **Clean-contaminated**
  - Normal flora without unusual contamination
  - Minimal spillage
- **Contaminated**
  - Fresh traumatic injuries (i.e. soft tissue lacerations, open fractures, penetrating wounds, etc)
  - Operative procedures with gross spillage or major break in aseptic technique
- **Dirty (infected)**
  - Heavily contaminated or clinically infected prior to operation
  - Perforated viscera, abscesses, or old traumatic wounds with retained devitalized tissue or foreign material
WOUND CLOSURE BASICS
Wound Closure Basics

• Basic Options
  • Sutures
  • Steri-strips
  • Staples
  • Dermabond (“glue”)

• Always EVERT
Wound Closure Basics

• Sutures vary in their capability to provoke infection, with catgut being the most "reactive" and polypropylene being one of the least "reactive" suture materials.

• Staples are less reactive than the least reactive suture (staple erythema).

• Micro-porous tape (e.g. steri-strips) is the least reactive of man-made wound closure materials.
Steri-strips

- Various widths (¼”, ½”…)
- Length cut so that there is 2-3cm of overlap on the skin (on each side)
- Combine with benzoin or mastisol (not betadine)
- Potential Uses:
  - With subcuticular sutures
  - Following staple or suture removal
  - For delayed closure
Staple Placement

• Easy to apply and allow rapid closure of wound
• Remember to EVERT the tissue edges
• Place staples at right angle to skin
• Hold the stapler in place until the other person has re-grasped in a new location
Staple Removal

- Grab the staple directly in the middle with the bottom tip underneath the staple
- Then squeeze the handles to release the staple from the skin
- Does it hurt?
  - Most say it “pinches”
SUTURE MATERIALS
Suture Material

• Generally categorized by three characteristics:
  • Absorbable vs. Non-absorbable
  • Monofilament vs. Multifilament
  • Natural vs. Synthetic
Absorbable Suture

• Degraded and loses tensile strength within 60 days

• Eventually eliminated in one of two ways:
  • Via inflammatory reaction utilizing tissue enzymes (natural absorbables)
  • Via hydrolysis (synthetic absorbables) → less inflammation

• When to use it:
  • Primarily used under the skin (e.g. subcuticular closure)
  • Also used in children when suture removal may be difficult (likely more scarring)
# Absorbable Suture Degradation

<table>
<thead>
<tr>
<th>Suture Material</th>
<th>Method of degradation</th>
<th>Time to degradation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catgut</td>
<td>Proteolytic enzymes</td>
<td>Days</td>
</tr>
<tr>
<td>Vicryl, Monocryl</td>
<td>Hydrolysis</td>
<td>Weeks to months</td>
</tr>
<tr>
<td>PDS</td>
<td>Hydrolysis</td>
<td>Months</td>
</tr>
</tbody>
</table>
Non-absorbable Suture

- Not readily broken down by the body’s enzymes or by hydrolysis
  - Ultimately encapsulated or walled off by the body’s fibroblasts
- “Permanent” (maintains tensile strength >60 days)
- Examples:
  - Naturals – Stainless steel, Silk
  - Synthetics – Prolene (polypropylene), Nylon, Ethibond
- When to use it:
  - Closing the abdominal fascia
  - Repairing superficial lacerations
  - Vascular anastomoses
  - Bowel anastomoses
Monofilament Suture

- Grossly appears as single strand; all fibers run parallel
- Causes less friction, thus less tissue trauma
- *Resists* harboring micro-organisms
- Ties smoothly, but requires more knots than multifilament (5-6 knots vs. 3 with silk)
- Possesses memory → tendency not to lie flat, but rather to return to given shape set by the material’s extrusion process or the suture’s packaging
- Preferred for skin closure b/c less tissue reaction, less traumatic, fewer infections, and better cosmetic result
- Examples:
  - Monocryl, PDS, Prolene, Nylon
Multifilament Suture

- Fibers are twisted or braided together
- Causes greater resistance in tissue, question of more trauma
- Greater ease of handling and tying
  - Higher coefficient of friction
  - Knots remain as they are laid down → fewer knots required, less likely to slip
- Increased infection risk
- Examples:
  - Vicryl (braided), Chromic (twisted), Silk (braided)
Natural vs. Synthetic

Natural Suture
- Biologic origin
- Causes intense inflammatory reaction
- Examples:
  - Catgut (purified collagen fibers from intestine of healthy sheep or cows)
  - Chromic (catgut treated with chromium salts to delay break down)
  - Silk

Synthetic Suture
- Synthetic polymers
- Do not cause intense inflammatory reactions (or at least cause a much less intense reaction)
- Examples:
  - Vicryl
  - Monocryl
  - PDS
  - Prolene
  - Nylon
Suture Selection

• Suture needs to retain strength until tissue is able to heal and support itself.
• Requirement for wound support varies by tissue type
  • Few days for muscle, subcutaneous tissue, and skin
  • Weeks or months for fascia and tendon
  • Long-term stability for vascular prosthesis
• Tissue reaction caused by suture affects healing
• Pliable for ease of handling and knot security
General Principles for Suture Selection

- When a wound has reached maximal strength, sutures are no longer needed.
  - Tissues that ordinarily heal slowly, such as fascia and tendons, should usually be closed with non-absorbable sutures. An absorbable suture with extended (up to 6 months) wound support may also be used.
  - Tissues that heal rapidly, such as stomach, colon, and bladder, may be closed with absorbable sutures.
General Principles for Suture Selection

• Foreign bodies in contaminated tissues may propagate infection.
  • Braided sutures have more surface area and crevices for bacteria to adhere to.
  • Use monofilament or absorbable sutures in potentially contaminated tissues.
General Principles for Suture Selection

• Where cosmetic results are important, close and prolonged apposition of wounds and avoidance of irritants will produce the best results.
  • Use the smallest inert monofilament suture materials, such as nylon or polypropylene.
  • Avoid skin sutures and close subcuticularly, whenever possible.
  • Under certain circumstances, to secure close apposition of skin edges, a topical skin adhesive (such as dermabond) or skin closure tape (such as steri-strips) may be used.
General Principles for Suture Selection

- Foreign bodies in the presence of fluids containing high concentrations of crystalloids may act as a nidus for precipitation and stone formation.
  - In the urinary and biliary tract, use rapidly absorbed sutures.
- Regarding suture size...
  - Use the finest size, commensurate with the natural strength of the tissue.
  - If the postop course may produce sudden strains on the suture line, reinforce it with retention sutures - remove them as soon as the patient’s condition stabilizes.
SUTURE SIZE

What’s bigger, a 2 prolene suture or a 2-0 prolene suture?
Suture Size

- Sized according to diameter with “0” as reference size
- Numbers alone indicate progressively larger sutures (“1”, “2”, etc)
- Numbers followed by an “0” indicate progressively smaller sutures (“2-0”, “3-0”, etc)

...3-0...2-0...1-0...0...1...2...3...
Suture Removal

When to remove…
- **Face**: 3-4 days
- **Scalp**: 5 days
- **Trunk**: 7 days
- **Arm or leg**: 7-10 days
- **Foot**: 10-14 days
Wound Closure Basics

- Handle tissue gently.
- Use fine-toothed forceps such as an Adson forceps on skin.
  - Do not use smooth forceps, as these crush skin
- Evert wound edges to maximize good epidermal approximation
  - Minimize the risk of scar depression, secondary to contraction during scar maturation.
Wound Closure Basics

• Approximate, don’t strangulate.
  • Wound edges should only be approximated.
  • Sutures that are too tight accentuate cross-hatching and cause ischemia of the wound edges, increasing the risk of infection.
Wound Closure Basics

• Proper suture placement
  • Enhance wound edge approximation
  • Minimize and redistribute skin tension
  • Allow for healing

• Loose approximation produces stronger wound margins, because proliferative activity can occur in the wound clefts.
NEEDLES AND SUTURE INSTRUMENTS
Needles

- Classified according to shape and type of point:
  - Curved or straight (Keith needle)
  - Taper point, cutting, etc.
- Most sutures come with suture material swaged onto the needle.
- The needle should be grasped about 2/3 of the way back from the point.
  - Grasping further back tends to weaken the needle and its attachment to the suture,
  - May also bend the needle.
Types of Needles

Curved
- Designed to be held with a needle holder
- Used for most suturing

Straight
- Often hand-held
- Used to secure percutaneously placed devices (i.e. central and arterial lines)
Types of Needles

• **Tapered**

• **Cutting**
  - **Regular cutting tips**: the cutting edge is on the inner curvature.
  - **Reverse cutting tips**: the cutting edge is on the outer curvature.

• **Diamond Point**: useful for attaching suture material and/or synthetic grafts to tendons or cartilage.

• **Blunt point**: these needle tips have no cutting edge and are used for friable tissues, such as the liver, where cutting and piercing would be detrimental.

• **Lancet, or Spatula**: primarily for Ophthalmic surgery, for the repair of muscle, retina, and delicate eyelid tissue. Cutting edge may be on the inner or outer curvature.
Tapered Needles

• Round body
• Used to suture soft tissue that is easy to penetrate (e.g. bowel, blood vessels, muscle, fascia, peritoneum)
• Produces the smallest hole, minimizing trauma
• Penetrating skin with a tapered needle is difficult and causes excess trauma (difficulty in penetration and the need to grasp the skin edge tightly with forceps). Consequently, you should never use tapered needles to suture skin.
Cutting Needle

- Triangular body
- Sharp edge toward inner circumference (the apex forms the cutting surface)
- Used to suture skin or tough tissue
- Produce a larger hole than tapered tips
- Cutting tips are not used intra-abdominally due to the risk of blood vessel or delicate tissue damage.
General Principles of Knot Tying

- Simplest knot for the material is most desirable.
- Completed knot must be firm, such that slipping is virtually impossible.
- Knots must be as small as possible to prevent excessive tissue reaction. Ends should be cut as short as possible.
- Excessive tension by the surgeon will cause breaking of the suture.
- Sutures used for approximation should not be tied too tightly (to prevent tissue strangulation).
- After the first loop is tied, maintain traction on one end of the strand to avoid loosening of the throw.
General Principles of Knot Tying

• Final tension on final throw should be as nearly horizontal as possible.
• Do not hesitate to change stance or position in relation to the patient in order to place a knot securely and flat.
• Extra ties do not add to the strength of a properly tied knot. They only contribute to its bulk.
• If the two ends of the suture are pulled in opposite directions with uniform rate and tension, the knot may be tied more securely.
• Specific methods of knot tying have been developed to increase surgeons’ efficiency and speed, while still providing the most secure type of closure.
Knot Tying

• **Two-handed square knot**
  - Easiest and most reliable
  - Used to tie most suture materials

• **One-handed square knot**
  - May be easier to place in deep and narrow openings
  - Attending preference

• **Instrument tying**
  - Useful when one or both ends of suture material are short
  - Commonly used technique for laceration repair
Knot Tying

• **The tensile strength of the suture determines the number of throws for a knot.**

• **General Guidelines:**
  - Silk: 3 or more throws
  - Absorbable braided: 4 or more throws
  - Monofilament (absorbable or non-absorbable): 6 or more throws
Forceps

• Used to create counter traction and control the position of the skin edge to facilitate passage of the needle.
• Hold forceps like a writing utensil
  • One arm is extension of thumb
  • Other is extension of index finger
• For skin, use fine-toothed forceps (e.g. Adson forceps)
• For other tissues, use without teeth (e.g. debakey forceps)
  • But avoid crushing the skin edges!!!!
Needle Drivers

- Most common method for holding: thumb and ring fingers slightly in the rings
- Some do **not** put their fingers into the rings and simply grasp the needle holder in their palm
- Tip of the needle holder should grasp the needle ~ 2/3 back from the point
- Needle holder and needle roughly perpendicular
- Try not to grab needles by their tips (they will become blunt)
- **NOTE**: Suture scissors similar
Suture Scissors & Cutting

• Hold scissors like a needle driver, using your index finger to stabilize and direct.
• Cut with the scissors’ tips, so that you don’t accidentally injure surrounding structures/tissue.
• How long should the tail be?
  • 1 mm (“on the knot”) for most deep sutures
  • 3-4 mm for most skin sutures and some deep sutures
  • 5-10 mm for some synthetic sutures (e.g. fascial closures and vascular sutures)
  • Attending preference – ASK!
SUTURE TECHNIQUE
Coordinated Movements

• **TIPS:**
  • Use the natural curvature of the needle
  • Alternate pronating and supinating

• **HOW TO (right-handed):**
  • Elevate skin edge with forceps in left, while the right is pronated with needle
  • Needle should penetrate the skin *perpendicularly*
  • Rotate the needle through the skin by supinating
  • **KEY TO SUCCESS:** Maintain the position of the skin edge using the forceps
  • Fully pronate the right hand and regrasp the needle on the other side
  • Complete the “bite” by supinating the hand to finish the needle’s rotation
Simple Interrupted

- **Advantages:**
  - Easy to place
  - Greater tensile strength
  - Less likely to impair circulation than the continuous suture

- **Disadvantages:**
  - Takes longer to place than the continuous suture
  - Increased risk of cross-hatch marks
Simple Interrupted

- Single stitches, individually knotted (all knots on one side of wound)
- Used for uncomplicated laceration repair and wound closure
- Always start AWAY from yourself and sew towards yourself
Running/Continuous Suture

**Advantages:**
- Quicker placement
- Useful for longer wounds in which wound tension has been minimized with properly placed deep sutures and good approximation has been achieved

**Disadvantages:**
- Risk of dehiscence if the suture material breaks
- Difficulty in making fine adjustments while suturing
- Some use a running locked suture for wounds under moderate tension or those requiring additional hemostasis b/c of skin edge oozing (may cause tissue ischemia)
Running/Continuous

- Made with one continuous length of suture material
- Used to close tissue layers which require close approximation, such as the peritoneum
- May also be used in skin or blood vessels
- Always start AWAY and sew towards yourself
Subcuticular (intradermal)

- Useful when there is minimal tension and the dead space has been eliminated

**Advantages:**
- Better cosmetic outcome
- Precisely approximates wound edges

**Disadvantages:**
- Does not provide significant wound strength
Subcuticular (intradermal)

- Usually a running stitch
- Intradermal horizontal bites
- Allows suture to remain for a longer period of time without development of crosshatch scarring
- No suture removal required
Horizontal Mattress

**Advantages:**
- Useful for wounds under high tension (provides strength and eversion)
- Added strength in fascial closure
- Also used in calloused skin (e.g. palms and soles)

**Disadvantages:**
- High risk of leaving suture marks
- High risk of tissue strangulation and wound edge necrosis
Horizontal Mattress

- Two-step stitch:
  - Simple stitch, then
  - Needle reversed and 2nd simple stitch made adjacent to first
  - Same size “bite” as first stitch
Vertical Mattress

- **Advantages:**
  - Precise approximation of skin edges
  - Maximal eversion
  - Reduces dead space
  - Minimizes tension across the wound

- **Disadvantages:**
  - Cross-hatching
  - More time to place
Vertical Mattress

Two-step stitch:

1. Simple stitch made “far, far” relative to wound edge (large “bite”)
2. Needle reversed and 2nd simple stitch made “near, near” inside 1st (small “bite”)
Summary

• Understand the general principles of wound healing and wound closure
• Possess basic knowledge of the types of sutures and needles
• Know how to use common surgical instruments and technique when suturing
References