Wound Management in the Emergency Departme nt

Hartmut Gross, M.D., FACEP

Objectives

After reading this chapter, the reader will be able to:

1. Understand the general process of wound healing.
2. Understand the different types of wounds and give examples of each.
3. List factors which affect wound healing and increase the risk of infection or other complication.
4. Be familiar with the different classes of anesthetics and maximum doses of commonly used agents. Also be able to list instances in which epinephrine is contraindicated.
5. Know the basic instruments, the suture materials and when which kinds are used, where, and for how long.
6. Understand the basic techniques of suturing including suture placement, spacing, buried knot techniques, and management of "dog-ears."
7. Understand issues related to special types of wounds including bites, puncture wounds, and foreign bodies. Understand the use of prophylactic antibiotics.
8. Know who should receive tetanus immunization and who should receive tetanus immunoglobulin.

Introduction

Literally millions of traumatic wounds are treated each year in emergency departments in the U.S. Wound management is an area of still ongoing research, much of which supports traditionally performed techniques, but some of which also is still trying to resolve controversial topics. The basic principles of wound care are simple, as long as one keeps in mind what the intent of the care being rendered is. First of all, one must remember that the wound heals itself. If the patient is not mortally wounded, then the wound will heal all by itself. The physician who believes that *he* made the wound heal is deluding himself and does not understand wound healing. So, what is the big deal and what are the doctors good for if the wound is going to heal no matter what? In essence, the objective is to restore tissue integrity, and function, while avoiding infection and morbidity, and minimizing scarring. To achieve this outcome, a thorough understanding of wounds is necessary.

Wound Healing

Critical to the management of wounds is a good understanding of how tissue heals. While the process is a continuum of overlapping steps, it is generally divided into several convenient phases.

Injury - While not technically part of the healing process, this is the moment that initiates the healing process.

Inflammatory -

Vascular - transient vasoconstriction lasting 5-10 minutes.

Cellular - leukocytes "stick to damaged vessel walls and migrate into surrounding tissue and begin phagocytosis of wound debris.

Fibroblastic - fibroblasts migrate into the wound at 48 to 72 hours. Also, local undifferentiated mesenchymal cells are transformed into fibroblasts. Presence of too much fibrin in the wound will hinder their influx. Neovascular / endothelial budding and capillary formation follows the influx of fibroblasts. This phase may last 2-4 weeks depending on the amount of necrosis, infection, and hematoma.

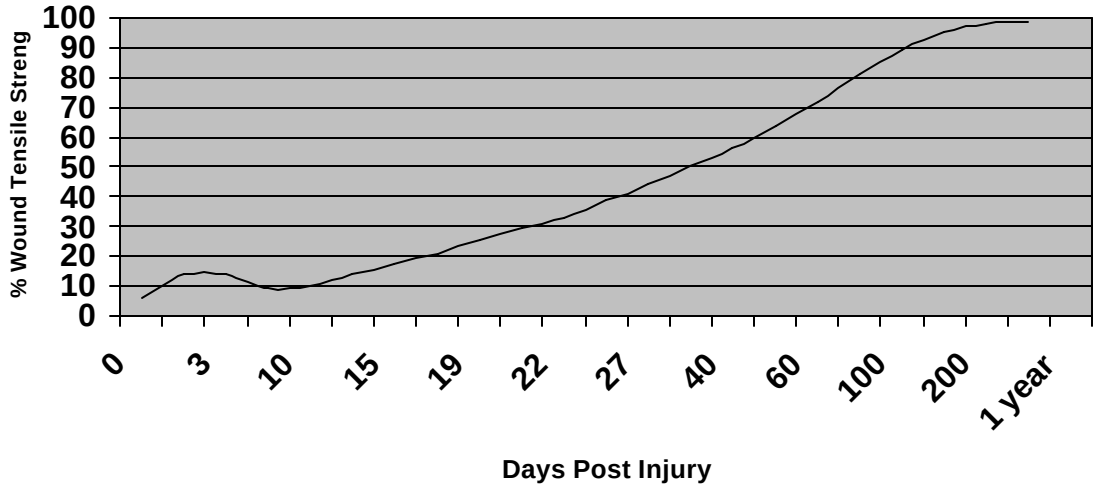
Contraction - starts in 3-4 days. It is due to the presence and action of myofibroblasts which reside in the granulation tissue.

Collagen Synthesis - deposition begins by day 4 and increases until week 2 to 3. Not surprisingly, the wound has its greatest bulk at 2-3 weeks. It is this component which gives the healing wound its gradually increasing tensile strength.

Remodelling Phase - crosslinking and remodeling of the collagen fibers continues

for the rest of the patient's life. It will occur quickly early on and later slow down. Patients should generally be instructed that the wound appearance 6 months to 1 year from the time of the injury will be fairly representative of the final outcome.

Table 1. % Wound Tensile Strength vs. Time



As can be seen in Table 1, a wound only has approximately 10-15 % of its original tensile strength at the time of usual suture removal (typically 7-14 days. See also Table 7.)
You may recall that at 21 days post-op, surgeons typically remove abdominal "retention sutures." While the greatest bulk of collagen in the wound is present at this time, there is still only 30 % of the original tissue strength.

A number of factors may impair the normal rate of wound healing. They are typically grouped and classified as shown in Table 2.:

Table 2. Factors Altering Wound Healing

Technical Factors
- Inadequate wound preparation
- Excessive suture tension
- Reactive suture materials
- Local anesthetics

Anatomic Factors
- Static skin tension
- Dynamic skin tension
- Pigmented skin
- Oily skin
- Body region

Associated Conditions and Diseases
- Advanced age
- Acute uremia
- Ehlors-Danlos syndrome
- Severe anemia
- Malnutrition
- Severe alcoholism
- Diabetes
- Hypoxia
- Peripheral vascular disease

Drugs
- Corticosteroids
- Penicillamine
- Anticoagulants
- NSAID's
- Colchicine
- Anti-neoplastic agents

Types of Wounds

Lacerations may be classified by the type of mechanism through which they are produced. *Shear* injuries are violations of tissue by a sharp object which causes very localized tissue damage but no injury to surrounding cells. Examples include a surgical incision, a laceration from a piece of glass, or a stab wound. *Tension* lacerations are produced by blunt mechanisms, generally with a tangential force component. The result is tissue tearing with ragged edges and contusion of adjacent tissues. Examples are lacerations from colliding with asphalt at high speeds, wounds from oblique blows with a baseball bat, and some types of industrial accidents. *Crush* or *compression* lacerations occur when skin is injured between an object and underlying bone. These lacerations may have a stellate appearance and are associated with a considerable amount of local tissue trauma. Resultantly, infection rates are higher and poor cosmetic outcomes are common. Examples of this type of wound include bottle and club blows to the scalp or extremities, and children with eyebrow lacerations due to falling against the coffee table. Finally, combinations of any of these mechanisms are possible.

Abrasions and burns are two other kinds of wounds. Their classification is based upon the depth of tissue destruction. First degree involves damage only to the epidermis. It is characterized by the presence of erythema and pain of otherwise intact skin. If there is any dermal involvement , as evidenced by blistering or bleeding or exposed dermis, the wound becomes classified as a second degree wound. Sensation is still intact and the tissue will heal by re-epithelializing from the deeper dermal elements (hair follicles and sweat glands). Small blisters should be left alone as long as they are completely intact as they are natural sterile dressings. Very large blisters which will probably rupture shortly anyway may be opened and treated with silver sulfadiazine (Silvadene™) cream (not on face) or combination polymyxin, bacitracin, neomycin (Neosporin™) ointment. If sensation is lost and the wound has a leathery or waxy appearance and the deeper dermal elements are destroyed, the wound is classified as third degree. These will need to heal by formation of granulation tissue and in-growth of epithelial tissue, or if larger than a few centimeters, may require skin grafting. Fourth degree wounds involve underlying muscle, bone, or tendon.

Anesthetics

Nearly all wounds will be associated with some degree of pain (exceptions are 3rd and 4th degree burns and patients with diabetic neuropathy). Pain control must be addressed at some point during a patient's visit. Frequently, some type of analgesia will be required even to adequately assess a wound. This may be in the form of systemic medication (PO, IM, or IV), regional anesthesia (nerve block), or local administration of some agent (topical or injected). The power of "verbal anesthesia" should not be underestimated and cannot be stressed enough as it may make a significant difference in the management of a patient (e.g. local anesthesia versus conscious sedation in a child).

Agents

Anesthetic agents are typically divided into 2 groups based on their molecular structure: amides and esters. The primary reason for the importance of this classification is the rare case of allergy to an agent. Patients allergic to an agent are likely to be allergic to other drugs in the same class. Therefore, an agent in the other class should be selected. It is felt that true allergy to amides (lidocaine and bupivacaine) is rare and is most often actually due to the preservative methylparaben in the the multidose vials; the preservative is an ester). Cardiac lidocaine does not contain the preservative and may be given initially as an intradermal test dose to check for true allergy. Another, unrelated medication which has been used by some is diphenhydramine (Benadryl™). It is suggested that a 0.5 –1.0% concentration can be used without risk of allergy. However, the drug is **not** approved for this use and the 2000 PDR still specifically lists its use as a local anesthetic as a *contraindication* because of the risk of local tissue necrosis.

Table 3. Commonly Used Local Anesthetic Agents

Medication	*e.g. Trade Name*	*Duration*	*Dose*
Esters			
procaine	Novocaine	1 hour	10-15 mg/kg 500-600 mg max.
tetracaine	Pontocaine	30-60 min.	Topical, eyes, 30 mg max
cocaine		1 hour	Topical, 150-200 mg max
Amides			
lidocaine	Xylocaine	1-2 hours	4.5 mg/kg
mepivacaine	Carbocaine	1-3 hours	5-7 mg/kg, 400 mg max
bupivacaine	Marcaine, Sensorcaine	6-8 hours	3 mg/kg, 175 mg max
Other			
diphenhydramine	Benadryl	30-45 min.?	See above contraindication

A useful quick trick to remember if an agent is an amide or an ester is to count the number of "i's" in the **generic** (not the brand) name. If there is only one, the agent is an ester; if there are 2 "i's", the drug is an amide. The pneumonic is right most of the time but as always, if you are unsure, look it up!

Epinephrine is frequently used in conjunction with a local anesthetic. Its use may be for a number of reasons, but they are all related to its vasoconstrictive properties. First, it will control oozing of blood in the wound, allowing for better inspection of the wound and less hematoma formation. This is particularly useful on very vascular areas such as the scalp.
Secondly, with the localized vasoconstriction, the local anesthetic is not washed out of the area as quickly, hence longer anesthesia time. Finally, because there is slower absorption into the systemic circulation, higher doses of anesthetic may be used in the patient. For example: instead of 3-5 mg/kg of plain lidocaine, 5-7 mg/kg of lidocaine with epinephrine may be used. Instead of 1-2 hours of effect, 2-3 hours of anesthesia may be achieved. There are several times when use of epinephrine is relatively, or even absolutely, contraindicated. Use of epinephrine should be avoided in any tissue which appears to have already significantly compromised blood flow. Additionally, it must not be used in any structure with a single or terminal blood supply: fingers, toes, tip of the nose, ear block, or penis. There are several reports of thumb necrosis secondary to accidental discharge of an Epi-Pen™ into the thumb. It injects automatically when pushed against a surface, normally the thigh, and is used in case of an anaphylactic reaction.

Nearly all patients complain of pain from the anesthetic agent as it is being injected. This is due to at least two factors. The first is the rate of injection. Rapid tissue distention causes pain and may be avoided by injecting slowly. Taking a bit more time here may add 1-2 minutes to the procedure, but may decrease time spent having to calm and reassure an otherwise frightened patient afterward, significantly. The second factor is due to the pH of the anesthetic agent. Lidocaine is stored in an acidic solution in which it is stabile. Buffering lidocaine with bicarbonate evens out the pH difference and makes the solution better tolerated. Unfortunately it cannot be stored for long periods of time as it breaks down. Buffered lidocaine is mixed 9cc of lidocaine with 1 cc sodium bicarbonate for a volume of 10 cc (Incidentally, bupivacaine cannot be buffered the same way).

Finally, anyone administering medications of any kind should be aware of common potential side effects of these medications. Side effects encountered from local anesthetic agents are typically dose related and include the following in gradually increasing doses:

CNS: restlessness, circumoral paresthesias, tinnitus, tremors, shivering, drowsiness, lassitude, amnesia, and seizures

Cardiovascular: bradycardia, decreased blood pressure, and heart block

Local Anesthesia

Prior to injecting any agent, an assessment of the injured area **must** be performed. This includes assessment of distal motor, sensory and vascular function and integrity. Any dysfunction should be recognized and documented before proceeding with injection of anesthetic agents. Sensory exam of the

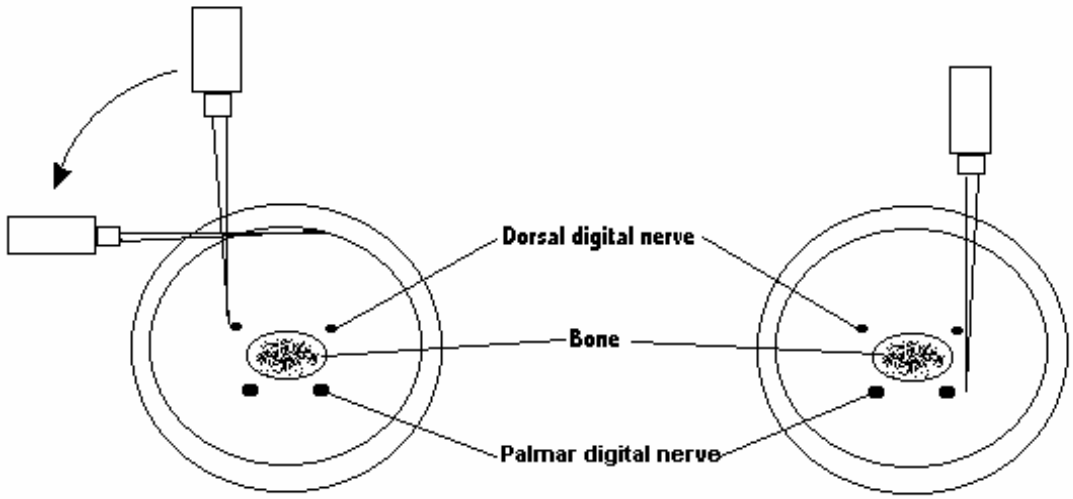
hand is particularly important to perform carefully, including checking two-point discrimination. This can easily and quickly be checked with a bent paper clip. Finally an inspection of the wound should be performed, as well as the patient can easily tolerate, to assess the severity the wound and see how the wound should best be managed and determine exactly what type of anesthesia is required.

Injection of local anesthetic agents should be performed with a 25, 27, or even a 30 gauge needle if available to minimize discomfort. Anecdotally, I have also found that children do better not seeing the syringe or needle before starting. So rather than loading and squirting a syringe like in the movies at the beside, I draw up the medication in another room and keep the syringe in my shirt pocket until the last possible moment and even then out of view. The injection should be made through the exposed wound edge; usually no pain is experienced as the needle is inserted and there is no increase in risk of infection. Going through the adjacent intact skin, however, causes extra pain and damages intact skin and should be condemned. Again, anecdotally, I warn my patients that the injection of the agent (and not the needle) will sting for about 5 seconds. I have children count slowly to five before I start and each time I slowly inject. Anxious patients seem to calm down better with this activity to keep them occupied, as well as with the assurance that I am not deceiving them and that there is an endpoint to their pain. Even though nothing works every time, I highly recommend trying the technique.
Typically, the anesthetic agent is deposited into the dermis around the edges of the wound so that the wound may be sutured painlessly. In areas where this will cause too much tissue distortion, particularly areas where cosmetic outcome is important, or the area is too great to infiltrate locally, a regional block or nerve block may be required. Most commonly performed blocks in the ED are fingers, hands, feet, mouth, and face.

Digital Block

The most commonly performed nerve block performed in the ED is the digital or ring block. It consists of depositing anesthetic agent around each of the four nerves in a finger or toe. Even though the palmar nerves supply most of the enervation to the digit, crossover from the dorsal nerve branches requires that they be block too. The technique begins with raising a wheal, dorsally over either side of the bone, somewhere distal to the metacarpal (metatarsal) phalangeal joint and proximal to the distal end of the web space. The needle is then directed perpendicular to the skin toward the dorsal nerve branch. Approximately 0.5 cc of agent (**NO EPINEPHRINE**) is injected here. The needle is advanced further to the level of the volar nerve and another 0.5 cc of anesthetic is deposited. The needle is then withdrawn. The needle is then reintroduced through the same wheal, this time tangentially as advanced to the opposite side and another wheal is placed here (this decreases the discomfort of sticking the needle through an unanesthetized site on the other side). The needle is then withdrawn; agent may also be injected across the top of the digit as the needle is being withdrawn. The needle is then reinserted through the new wheal and the procedure repeated. Wait approximately 5 minutes and test distal sensation before proceeding with the laceration repair. Occasionally the digit will require injection of additional medication (See Diagram 1).

Diagram 1. Digital Nerve Block Technique



Topical Anesthesia

Another method of analgesia involves application of a topical agent. It most often used in children and may induce sufficient anesthesia by itself or ameliorate the pain of subsequent injection of additional medication. This topical agent is often referred to as LAC, or LEC [lidocaine 4%, adrenaline (epinephrine) 0.5-1%, and cocaine 4-11.8%], or TAC (tetracaine 0.5%, adrenaline 0.5-1%, and cocaine 4-11.8%). Typically 10cc of medication are used.

A small amount of cotton is soaked with a portion of the agent and is gently stuffed into the wound so the cotton has very good contact with the wound edges (do not simply lay the cotton on the wound-it won't work) and leave in place for 10 minutes. Then reapply for 10 more minutes. The result should be a wound with no oozing and an area of blanching around the edge and good anesthesia for about 20-30 minutes. Best results are achieved on relatively thin skin. There are rare reports of seizures and death secondary to topical anesthetic use felt to be related to use on, or close to, mucosal surfaces with more rapid systemic absorption.

Skin and Wound Preparation

As noted before, a wound must be thoroughly assessed. A preliminary inspection will give you an idea of what kinds of injuries you may expect to find. When bleeding is present, it is best controlled by direct pressure. This means using one or two fingers if possible, as opposed to dumping a box of 4x4 gauze over the area and applying an ACE elastic bandage around the limb. The latter usually doesn't work because the pressure is too spread out to compress the damaged vessels adequately. This is a common mistake. Focal pressure for ten minutes will generally control most bleeding. Clamps should never be blindly placed into the wound. Remember that nerves run alongside vascular structures. They are very likely to be injured with clamps. Tourniquets provide another option but must be used with discretion and only for very short periods of time. They are rarely needed for life threatening hemorrhage, but they are frequently used to achieve a bloodless field. You can't see what is going on under a constant re-accumulating pool of blood, therefore, proximal control of blood inflow to the wound is an invaluable tool. Blood pressure cuffs make good tourniquets so that this bloodless field can be achieved and the wound may be adequately assessed. The extremity should be lifted to passively drain some of the venous blood as well as create a small arterial pressure gradient. Additionally, an elastic bandage may be wrapped around the extremity to mechanically force blood out of the extremity. The blood pressure cuff is then inflated above the level of the patient's systolic blood pressure (20-30 mm Hg above is frequently adequate. Some authors advocate inflating to 300 mm Hg), the bandage removed, and the extremity lowered. The cuff will be painful, so work should proceed quickly and efficiently. The cuff should not be left inflated for longer than 15 minutes, not because of tissue necrosis, but because of pain from the cuff. The procedure may be repeated if necessary.

All wounds (excepted those created in the operating room) are contaminated with debris and bacteria to some degree. To decrease the risk of infection, all wounds should be cleaned. This may be achieved in several manners, but before proceeding, the wound should be adequately anesthetized.

Hair removal is generally the first consideration. Unless hair strands are continuously in the way and/or at risk for being sutured into the wound, they may be left in place. Sometimes, removal of a tiny strip of hair may be necessary. Often, hair may be wet and teased down on either side of the wound to get it out of the way. Scissors are probably the best method for removing hair (it has been shown that shaving shin on the day prior to surgery actually causes additional skin nicks and increases the incidence of wound infection. Whether or not this extrapolates to the ED setting in unknown.) **Never shave eyebrows!** They are reported to have a tendency to grow back erratically resulting in poor cosmetic outcome.

The next step is some method to dilute the bacterial load as well as clean out debris. This is best accomplished with irrigation of the wound. This may easily be accomplished using normal saline, a 30 cc syringe, and an 18 gauge catheter. The syringe is loaded and squirted at full force each time from about 3 mm distance. This provides maximal irrigation and "pressure washing" (at about 25 psi.) without causing tissue damage.
This is repeated so that a wound is irrigated with roughly 50 - 100 cc for every cm in wound length (a good surgical adage to remember: "*dilution is the solution to pollution*").
It is a good idea to wear a face shield (or at least eye protection) and a water resistant gown as there will be a significant amount of back spray and you *will* otherwise get wet and possibly be exposed to HIV and

hepatitis B. There are some neat devices to assist in the irrigation process: Zerowets are small dome shaped devices attached directly to the end of the syringe and have a built-in nozzle so that the back spray is contained. Another device is a self-reloading syringe, which connects to an IV solution bag. After you draw-up, spray with full force, and irrigate with 1000 cc of saline, you will find your hand to be quite tired and/or sore. Remember that these are niceties, not necessities, and they do add to the patient's bill. It is a good idea to try to catch the irrigation fluid rather then letting the patient lie in it or have it run all over the floor. Aside from being messy, you will have created a dangerous work area for your self (your nurses will like you better too). A kick bucket under the main drip area and some towels on the floor will work nicely. After you have irrigated a wound thoroughly, especially a particularly dirty wound with skin flaps, close inspection may reveal more dirt ground into the tissue. This may require patiently sitting there and picking out each piece.

Selection of a wound cleanser must be considered next. The following table lists commonly used agents, their pros and undesirable side effects.

Table 4. Commonly Used Wound Cleaning Agents

Product/ Agent	Benefits	Side effects/ Precautions
Water	Inexpensive, Universal solvent	Hypotonic, will cause cell swelling and lysis
Saline	Iso-osmotic to tissue, no tissue toxicity	No germicidal activity
Hydrogen Peroxide	Good germicidal activity Good mechanical debridement of wound via effervescent activity	Very tissue toxic
Povidine-Iodine Betadine™ solution Betadine™ scrub	Excellent germicidal activity May be used around eyes and in mouth safely	**Solution** (green label) is very tissue toxic in stock solution (10%). When diluted to 0.001% (essentially clear with faint hint of brown color, it is still germicidal but not tissue toxic. **Scrub** (yellow label) is an external skin detergent and should **never** be used in a wound
Phisohex™	Good germicidal effects Once used commonly, then relegated to hand cleaner.	Associated with kernicterus in infants. Product is rarely seen anymore
Chlorhexidine Hibiclens™	Excellent germicidal activity	Tissue toxic. Keep out of eyes, ears and mouth
Alcohol	One of the best bactericidal and viricidal agents	One of the most tissue toxic agents
Sure Clens™	Nonionic polymer which is essentially painless in wound. No tissue toxicity. Has detergent qualities which help to float debris out of the wound.	No germicidal activity

As can be seen in the table, each product has its own unique qualities and applications. A thorough familiarity with each agent is highly recommended.

Instruments and Materials

Before beginning with the wound repair, is important to have all the necessary supplies assembled at the bedside.

- This begins with barriers: Face shield, water-repellant gown, sterile gloves, and sterile drapes.
- A syringe and additional anesthetic agent is often useful as well
- A good bright overhead light source, positioned so that your head will not immediately be in the way.

- A stool to sit on or the stretcher raised to a comfortable height when you stand. This point should not be underestimated. One's back quickly gets tired hunched over even for short periods of time.
- Gauze sponges
- Instruments are typically already pre-packed into a tray. They include towel (not skin) clamps, skin hooks, smooth and toothed pickups, straight and curved hemostats, a scalpel, a needle driver (holder), suture scissors, and medicine cups (shot glasses) for anesthetic and antiseptic solutions, and a small basin for saline. They also have a supply of gauze sponges and several sterile towels. Fine suture or "plastics" trays will typically have more and finer instruments, but are over-kill for most minor laceration repairs.

Here are a few additional tips on each of the major instruments:

Towels - Are useful to keep hair down and out of the way. I can not recommend covering a patients eyes and nose routinely when closing facial lacerations. It makes patients very claustrophobic as well as uncomfortable. Drapes often make you forget about your patient under them while you are focused on the wound. While it is OK and encouraged to stabilize your hand against the patient, don't lean on the drapes (and hence your patient).

Towel clips - These may be useful in securing the towels which have positioned around the wound. Do not clamp them into the skin as you may have seen done in the OR on patients under general anesthesia (Incidentally, some patients complain of more pain from the towel clamp site than the main wound).

Pick-ups (forceps) - These come in smooth and toothed. The smooth should be used only very gently as they will crush tissue. They are generally used for vascular and bowel handling. For skin, the toothed forceps should be used.

Hemostat - Very useful for grasping and clamping well visualized bleeding vessels until they can be ligated. They are often used for loading and unloading a scalpel handle with a blade or removing a needle from a syringe. They are of course self retaining.

Needle driver - Shaped much like a hemostat, this instrument has a sturdier, wider jaw with or with out teeth. The smooth jaw is usually on small drivers for holding small needles without allowing the needle to spin. Larger drivers for larger needles have finely serrated ridges. Additionally, a needle driver's jaws come together flat, while a hemostat comes together at the point first and then gradually closes in the center with increased pressure on the handle. This is why suture slips out of the hemostat and not the needle holder when instrument tying.

Skin hooks - They are sharp and dangerous. Often you will need an assistant to hold these while you use other instruments to explore or repair the wound.

Scalpel - Occasionally wound edges are jagged or already showing signs of necrosis and must be trimmed. The scalpel will make a straight cut with minimal adjacent trauma.

Suture Scissors - These are for cutting suture. Cutting tissue with these will cause adjacent crush injury.

- Suture material is the final component (see next section)

Suture Materials

By now the decision has been made that active intervention will be required, but there are still many choices to make. This begins with deciding whether or not to use Dermabond™ (glue), Steri-stips™ (butterflies), thread (suture), or staples.

Dermabond™ is a rapidly drying glue which may be applied topically (NOT into the wound) to hold he skin edges together. It can be used for small lacerations which are relatively superficial and where the skin edges have no tension pulling them apart. Application typically requires two people: one to hold the edges

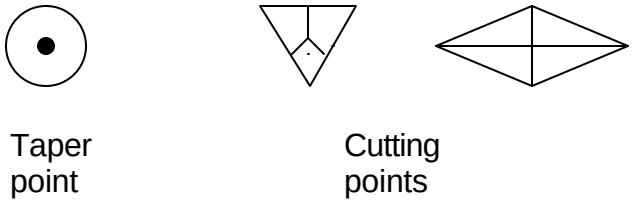
together, the other to apply the glue. Caution must be used not to glue the assistant to the wound. The glue dries in 15-30 seconds, depending on how thick it is applied.

Steri strips™ are simply tapes applied to hold the skin edges together. Like the skin glue they have no use for deep wound closure alone. They will not work if there is much tension across the suture line. They may not work in some children who may play with them and pull them off prematurely. They are painless to apply, however, which makes them very appealing. Additional adhesion may be obtained by applying tincture of benzoin to the skin edges (it will cause pain if inadvertently introduced into the wound).

Staples are available in pre-sealed staple guns which apply the staple. They are quick to apply, sometimes requiring little or no local anesthetic (since the anesthetic agent hurts too, you can give the patient the option). For good placement, the skin edges need to be held symmetrically with the edges everted somewhat. This implies that you should have an assistant. The cosmetic result is not as good as with sutures, hence their use is limited to the scalp, back and extremities.

Sutures come in many varieties. The suture material may be swaged onto the needle (stuffed and crushed into the hollow end of the needle), or be threaded into an eyed needle. The former is typically used. Needles are also classified by the type of point they have. When the tip is viewed in cross section, it may appear round indicating a *tapered* needle (it basically has a cone shape). It may appear triangular or diamond shaped in cross section indicating it is a cutting needle (the tip is basically a 3 or 4 sided pyramid shape). The edges actually will cut slightly into the tissue making it easier for the needle to pass. The taper needle simple pushes tissue aside and gradually distracts it until the hole is large enough for the needle to pass through. The packaging will indicate with a small symbol which type of needle it contains.

Diagram 2. Needle Tip Classification



Taper needles have little role in the ED. They are principally used for bowel and vascular repairs. Cutters, however, are great for fascia, and skin. If you are having trouble pushing a needle through tissue or bending a needle you might check and make sure you didn't accidentally pick up a tapered needle. There are also other types of specialty honed points available for special uses beyond the scope of this discussion.

Next, there are straight and curved needles. Straight needles are most often found in kits for placing vascular accesses such as central venous line kits. These are long enough that they may be used without a needle driver. They come with cutting tips. Curved needles are available indifferent varieties based on how large an arc they make. They may be ¼ circle, 3/8 circle, ½ circle, or 5/8 circle. The thickness of each needle will be determined by the size thread to be used.

Suture material comes in different sizes, with the ones used most commonly in the ED ranging from 0 to 6-0 (Sizes actually range from #5 to 10-0).

Table 5. Typical uses for Different Size Suture Materials

#2-#5	bone and tendon repair	String size
#0-#1	heavy fascia repair and securing vascular access lines	
#00 to4-0	standard for area under moderate to minimal tension 3-0 and 4-0 most commonly used	
5-0 to 7-0	hands, face, abdominal vascular anastomoses	Hair size
8-0 to 10-0	microvascular and eye repairs	Microscopic

Finally the type of suture material must be decided upon. Here again there are several considerations. The first is to decide on an absorbable or non-absorbable suture. Absorbable suture will be used on mucous membranes and subcutaneous tissue while non-absorbable suture is used on skin and sometimes fascia. Next one must decide on the specific type of material to use. In Table 6., you will see an extensive list of available suture materials (purely as a reference and not to be memorized). Choice will depend upon how long support from the suture material is desired, how reactive it is, whether or not it is braided, or if infection is present.

Table 6. Types of Suture and Examples

Absorbable

1. Catgut (nowadays made from cow or sheep tendon)
   a. Plain- very reactive and dissolves in about 1 week
   b. Chromic- chromic acid treatment renders it less reactive.
   It lasts about 2-3 weeks
2. Polyglycolic acid- Dexon (lasts about 4 weeks)
   Maxon (lasts about 6 months)
3. Polyglactic acid- Vycril (lasts about 4 weeks)
4. Poly dioxanone- PDS

Non-absorbable

1. Silk-fairly reactive, frequently gets "spit" out of wound.
   Now most commonly used to secure lines and tubes.
2. Cotton
3. Polyester- Dacron, Dermalene, Merselene, Teflon(Tevdek), Silicone (tri-cron), and Polybutilate (Ethibond)
4. Nylon- Dermalon, Surgilon, and Ethilon
5. Polyprophylene- Prolene and Surgilene
6. Stainless Steel (yes, it comes on a needle and is sewn. It is not used much, but occasionally you may see it on a patient's x-ray.)
7. Staples
8. Skin tape

Some of the sutures are braided and some are not. Braided suture tends to handle easier and is stronger, but it has a larger surface area and has a higher infection rate than monofilament suture.

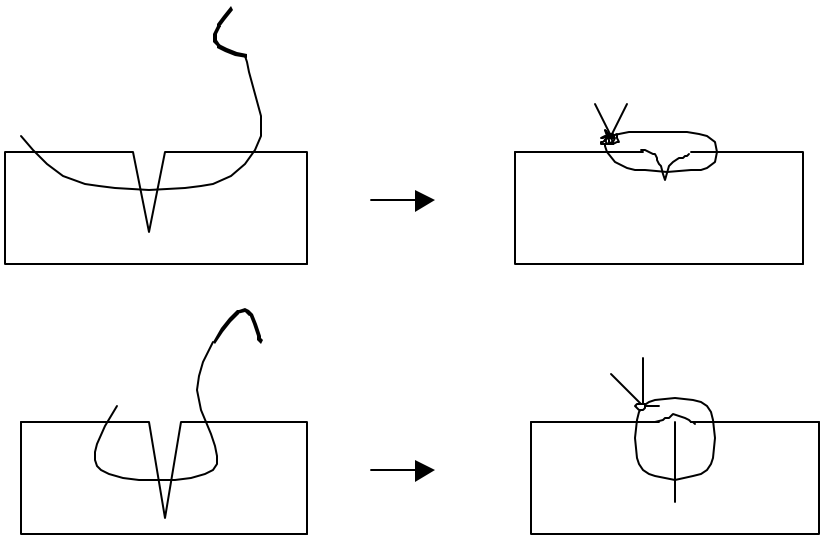
Basic Suture Techniques

Wound closure may be undertaken by primary, secondary, or tertiary intent. Primary closure is a repair immediately after the injury. Secondary intent refers to allowing the wound to scar and heal in by itself. Tertiary closure is a delayed closure undertaken on dirty wounds in which the chance of infection is unacceptably high. Therefore, the wound is packed open with frequent dressing changes to clean the wound and allow for a rich vascular bed to grow in over the next 4 or 5 days, after which the patient is brought back and the wound is closed then. The infection rate with tertiary closure is essentially 0% as opposed to approximately 5% with primary closure.

Rather than reviewing the step by step methods for placing a stitch and how to tie a knot, which you can review in any basic suturing manual, some pointers to make your work easier and outcome better are listed below.

- Evert wound edges. Inverted edges will leave an eventual dimple, which will cast a large shadow in tangential light. This is a very undesirable cosmetic result. To achieve evertion, the "bite" with the needle should be deeper than wide. See Diagram 3. below. Note that that path of the suture is slightly pear shaped. Shallow "bites" will invert the edges.
- Sutures should enter the skin at a right angle to the skin.
- Follow the curve of the needle (twist your wrist).
- Grasp the edge of the wound your are presently passing the suture through with forceps to stabilize the tissue.
- Make sure the suture is the same depth on both sides

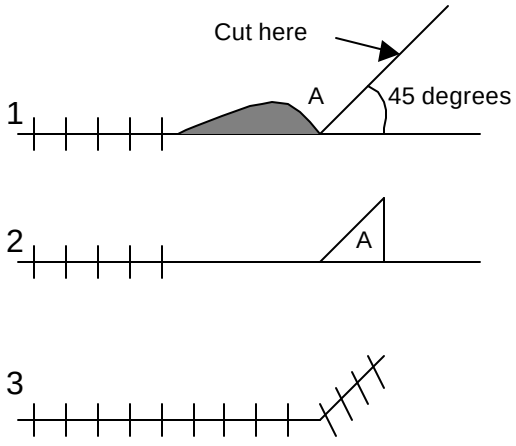
Diagram 3. Suture Placement to Optimize Wound Edge Evertion



- Don't be greedy. Take each side at a time instead of trying to pass the suture through both sides in one bite.
- Sutures should be place close enough and tight enough to simply approximate the wound edges. Use only as many sutures as needed to achieve this result.
- The pattern formed by successive sutures should roughly be a square; i.e. if the sutures are 3 mm back from the edge on each side, then the sutures should be placed approximately 6 mm apart from each other.
- Be gentle with the tissue.
- Don't stand in front of your light.
- Don't be afraid to remove one or several sutures if the wound is not coming together like you want. And if your patient asks why you removed a stitch, "Because I didn't like the way it looked," is a perfectly good response. Your patient wants the wound to look good too.
- Remove "airknots." They obviously aren't holding anything and only promote more scarring.
- Use "surgeon's" knots instead of "granny's." Lay each hitch down flat.
- Deep sutures or buried sutures should be absorbable with the knot placed at the bottom of the wound instead of at the top. Otherwise the knot and the reaction around it may be palpable through the skin. This is done by starting the stitch placement on one side at the bottom of the wound and coming up through the skin on that side. Next, the needle is passed into the skin on the other side and comes out of the bottom of the wound on that side; then a knot is tied.

"Dogears" are another problem which bears mentioning. They occur when the edge of one side of a wound is longer than the other side. As the wound is closed, a pucker emerges on one side. This is easily corrected by extending the laceration at a 45^{B} angle toward the side of the tissue buckle (See Diagram 6.). Then the newly created flap of tissue (A) is lain flat on top of the other skin and the excess flap is trimmed away. Then the laceration is closed as usual. The final result is a hockey stick shaped wound.

Diagram 4. Management of "Dogear"



Dressings and Splints and Care

After the wound is repaired, the area should be thoroughly cleaned of blood and skin prep agents. A topical anti bacterial ointment may be applied. Next a non-adherent dressing may be applied (e.g. Adaptic™ or Xeroform™) or simply a light gauze dressing. If some wound compression is required to inhibit additional hematoma formation, a bulky dressing may be used. Sometimes there is concern that the sutures may be ripped out by flexion of an extremity. Splints may be required to limit activity until the wound is in a more advanced stage of healing.

The epithelial layer of skin is usual closed within 48 hours. Some surgeons will say the wound is water repellant in 6-8 hours already. Patients should be instructed to keep the wound clean and free of eschar at home. This may be achieved with ½ strength peroxide or soap and water. Soaking of the wound for any prolonged period is to be discouraged strongly, while running water over the wound briefly during a shower is fine. Wound checks in 48 hours are generally recommended. Additionally the patient should be instructed of signs of infection to look for: *calor, rubor, tumor, and dolor* (heat, redness, swelling, and pain).

Remember that patients will need the issue of pain control addressed. Minor wounds will require little more than acetaminophen or ibuprofen. Burns are likely to require narcotics.

Suture Removal

Suture removal is dictated by several factors. The first is the usual rate of wound healing (see Table 1.). Next is the amount of tension across the wound. If the wound is on a extensor surface across a joint line then flexion of the extremity may place a large amount of tension across the suture line and cause in to rupture if the sutures are removed too early. General guidelines are listed below (see Table 7).

Sutures left in too long will leave scars in and of themselves. Epithelial "tubes" form around the suture from epithelial cells, which have migrated along the material. They can become permanent. Suture removal does not always require a "suture removal set" which typically contains a sterile pick-up and scissors and a piece of gauze. The set adds considerable expense and the same result can usually be achieved with a pointed scalpel (11 blade).

Table 7. Guidelines for Suture Removal

Site	Days Until Removal
Scalp	6-7
Face	4-5
Trunk	7-10
Arm	7-10
Leg	8-10
Joint	8-14
Hand	7-12
Foot	7-12

Tetanus Prophyllaxis

The following table concisely lists factors which delineate what constitutes a tetanus prone wound, what the time lines are for the duration of effectiveness of a tetanus booster injection, and who should receive a booster, immunoglobulin, or nothing at all.

Table 8. Anti Tetanus Prophylaxis, Wound Classification, Immunization

Wound Classification			Immunization Schedule				
Clinical Features	Tetanus Prone	Non-Tetanus Prone	History of Tetanus Immunizations	Tetanus Prone Wound		Non-Tetanus Prone Wound	
Age of Wound	> 4 hours	#4 hours		Td[1,2]	TIG	Td	TIG
Configuration	Stellate, avulsion	Linear	Unknown or <3 doses	Yes	Yes	Yes	No
Depth	>1 cm	#1 cm	3 or more doses	No[3]	No	No[4]	No
Mechanism of Injury	Missile, crush, burn, frostbite	Sharp surfaces (glass, knife)					
Devitalized Tissue	Present	Absent					
Contaminants (dirt, saliva, etc.)	Present	Absent					

[1] Td-Tetanus and diphtheria toxoids adsorbed (Adult).
[2] TIG-Tetanus ImmuneGlogilin Yes if wound >24 hours old. For children <7 yo, DPT (DT if pertussius vaccine contrindicated). For persons > 7 yo, Td preferred to tetanus toxoid alone.
[3] Yes if > 5 years since last booster.
[4] Yes if > 10 years since last booster.

Bites, Puncture Wounds, and Foreign Bodies

Animal bites are unfortunately frequently seen in the ED. They are by definition contaminated wounds. Cat, dog, and human bites are the most common causes and each has some unique characteristics. Cat bites tend to be puncture wounds. Puncture wounds are nearly impossible to irrigate to the bottom of the wound. As a result, if closed primarily they have a high rate of infection. The most common organisms are the Gram + skin pathogens, Staph and Strep. But special organism carried by cats and occasionally dogs is *Pasturella multocida*. This bacteria is very sensitive to penicillin. Dog bites on the other hand tend to be lacerations rather than puncture wounds. These can more readily be thoroughly cleaned and repaired primarily. The other bite is a human bite. Its classic presentation is that of an individual with a laceration over a metacarpal-phalangeal joint, sustained in a fight in which the skin was broken on a tooth. These wounds are at risk for joint penetration and contamination with *Eikenella corrodens.* This too is susceptible to penicillin but with joint involvement will require operative debridement if infection develops.
One final consideration related to animal bites is consideration of the possibility of transmission of rabies. This is particularly important in bites involving skunks, raccoons, bats, foxes, cattle, and dogs. Rodents, rabbits, hares, chipmunks, rats, and mice are not carriers.

Puncture wounds to the foot present another common problem seen in the ED. The classic story is that of stepping on a nail which penetrated the shoe or boot and skin. As a puncture wound, it can not be thoroughly cleaned. It is generally recommend to excise a small plug of tissue and irrigate the wound. Osteomyelitis is a concern and *Pseudomonas* is an offending organism which is sensitive to ciprofloxacin. Effectiveness of this therapy is controversial.

Foreign bodies may present interesting and unusual dilemmas. They may include wood splinters, glass, metal (needles, bullets, BB's), pencil leads, etc. Some foreign bodies may be left in place as long as there is little risk associated with their particular location. Metal can of course be seen on x-ray. Most glass can be seen. Wood is very difficult to visualize on x-ray but must be removed. Fishhooks can present a challenge because of their barb, however, there are multiple techniques described for removing them. It easy to spend a large amount of time trying to find a small foreign body in a small wound and it is frequently unsuccessful. Fluoroscopy may be helpful.

Prophylactic Antibiotics

This is an extremely controversial topic. It is known that patients who have therapeutic tissue levels of an antibiotic at the time of injury (surgery) have a decreased incidence of wound infection. Obviously this is not an option for patients presenting to the ED with a wound. Some experiments have suggested that there may be some protective effect if the antibiotics are started within 3 hours from onset of the wound. Few physician will argue with use of prophylactic antibiotics in an infection prone wound – crush, dirty, bites, deep and complex wounds or in an immunocompromised host. It is generally agreed that tissue has usually regained its immune state within 4 days, hence prophylactic antibiotics may be discontinued by day four.

Conclusion

Keep in mind that no matter how good you may perceive the final result, if you didn't remind or teach the patient that THERE WILL BE A SCAR, no matter who does the repair or how, you may have an unhappy patient. Many patients have the misconception that placing stitches prevents scar formation. It behooves you to dispel this myth early.

Adhering to all of the concepts described in this chapter will optimize your chance of a favorable outcome. When the functional and cosmetic out come is excellent, both you and the patient will be very satisfied. And that, after all, is what medicine is all about.