CHAPTER 52

Wound Management Principles

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PRINCIPLES

The goals of emergency wound treatment are to restore function, repair tissue integrity with strength and optimal cosmetic appearance, and minimize risk of infection. Risk of infection depends on the location, mechanism, host, and care. The risk for a clean facial wound produced by incision is less than 1%, whereas a dirty crush injury to the lower extremity may have more than a 20% risk. Wound infection generally results in delayed healing, decreased strength, and a poor cosmetic result. These facts highlight the need for high-quality wound care. Understanding the biology of wound healing and the technical aspects of wound treatment facilitates emergency management of these patients.

Emergency clinicians must also be aware of the medicolegal risk associated with soft tissue injuries. Including injuries to the hand, wound-related complaints are the fourth most common cause of malpractice claims against emergency clinicians. Missed foreign body, wound infection, and missed tendon or nerve injury are the most common complications leading to these claims.

Anatomy of Skin and Fascia

An understanding of skin anatomy leads to better appreciation of wound closure concepts and techniques. The skin is a complex organ that protects the body against bacterial invasion and ensures thermoregulation. The skin also helps to regulate water content and register sensory stimuli.

The skin and fascia vary in thickness from 1 to 4 mm, depending on the part of the body. The epidermis, the outermost layer, is several cell layers thick. The most important parts of the epidermis are the stratum germinativum (basal layer), where new cells originate, and the stratum corneum, the outermost cell layer that gives the skin its cosmetic appearance. The layer of skin directly beneath the epidermis is the dermis. The much thicker dermis is primarily composed of connective tissue. The dermis is the key layer for the ultimate healing of skin wounds. Optimal healing and minimal scar formation depend on the removal of debris and devitalized tissue from the dermis. The dermis also functions to anchor sutures placed percutaneously or subcutaneously.

The superficial fascia lies directly beneath the dermis and encloses the subcutaneous fat. This space must be irrigated and débrided to decrease the risk of infection. The deep fascia lies beneath the fat and is a strong, off-white sheath that covers and protects the underlying muscles and helps prevent superficial infection from spreading to deeper tissues. The deep fascia must be closed to maintain its protective and functional roles.

Wound Biology

Normal wound healing is a well-choreographed sequence of biologic events. It is described as an orderly process, but it actually represents multiple phenomena that occur simultaneously. These events include coagulation, inflammation, collagen metabolism, wound contraction, and epithelialization. Maintaining the balance of these events is crucial for normal healing. Delaying any of the stages may result in a weak closure and dehiscence. Prolonging segments of the process may affect the ultimate scar appearance.

Soon after tissue integrity is altered, the process of coagulation begins. Platelet release factors initiate and enhance a response from inflammatory cells. Capillary permeability increases to allow white blood cells to migrate into the wound. Neutrophils and monocytes act as scavengers to rid the wound of debris and bacteria. Monocytes transform into macrophages, which seem to have a major role in subsequent healing phenomena. In addition to providing wound defense, macrophages release chemotactic substances, signaling other monocytes to stimulate fibroblast replication and trigger neovascularization.

Collagen is the principal structural protein of most tissues of the body. Normal tissue repair depends on collagen synthesis, deposition, and cross-linking. Fibroblasts synthesize and deposit collagen compounds 48 hours after injury. Immature collagen is highly disorganized because it has a gel-like consistency.

After a series of enzymatic processes, characteristic fibrils are produced. Subsequent intermolecular cross-links are responsible for a major portion of the strength of the collagen fibril. The entire process depends on tissue lactate and ascorbic acid and is directly related to tissue arterial carbon dioxide partial pressure. In the absence of vitamin C, prolyl and lysyl hydroxylase do not activate, and oxygen is not transferred to proline or lysine. Underhydroxylated collagen is produced, and characteristic collagen fibers are unable to form. Wound healing is poor, and capillaries are fragile. Without oxygen to hydroxylate proline and lysine, a local condition resembling scurvy tends to occur.

Under normal conditions, collagen synthesis peaks by day 7, coincident with rapid increases in tensile strength. The healing wound has the greatest mass at 3 weeks but remodels itself during the next 6 to 12 months. However, the wound achieves less than 15% to 20% of its ultimate strength by 3 weeks and only 60% by 4 months.

Wound contraction is the movement of whole-thickness skin toward the center of the skin defect. Immediately after injury, the wound edges retract and increase the size of the defect. Normal skin tension along the lines of minimal tension produces this
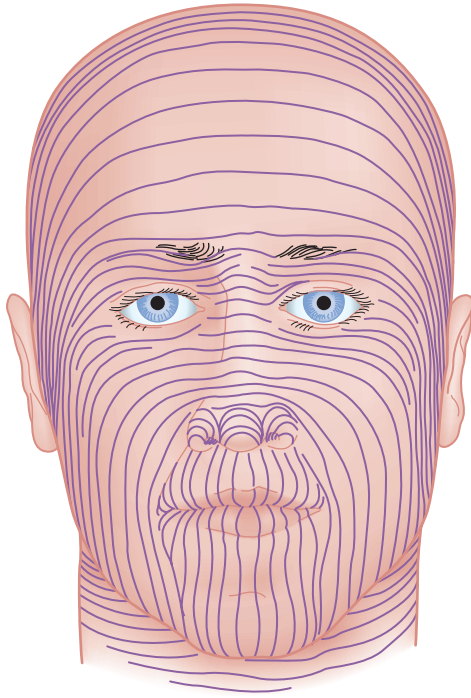
Fig. 52.1. Skin tension lines of the face. Incisions or lacerations parallel to these lines are less likely to create widened scars than those that are perpendicular to these lines. (Adapted from Simon R, Brenner B: Procedures and techniques in emergency medicine, Baltimore, 1982, Williams & Wilkins; as published in Trott A: Wounds and lacerations: emergency care and closure, ed 2, St Louis, 1997, Mosby.)

Fig. 52.2. Skin tension lines of the body surface. (Adapted from Simon R, Brenner B: Procedures and techniques in emergency medicine. Baltimore, 1982, Williams & Wilkins; as published in Trott A: Wounds and lacerations: emergency care and closure, ed 2, St Louis, 1997, Mosby.)

retraction (Figs. 52.1 and 52.2). Wounds perpendicular to these lines are under greater tension and result in a larger scar.

During the next 3 or 4 days, the wound size shrinks as its edges move toward the center. This phenomenon is independent of epithelialization, and the presence of collagen is not necessary for it to occur. This process is considered beneficial to healing and should not be confused with contracture that results from scar shortening.

Contracture becomes more apparent when the normal healing process is prolonged. The effect is a disfiguring hypertrophic scar. Optimizing the duration of the inflammatory phase and minimizing wound tension help to produce a more "appealing" scar.

Epithelialization is a mechanism in the healing process whereby epithelial cells migrate across the wound. Mitosis appears at the wound edge near the basal cell layer within hours of injury. Eschar or other debris impedes this process. When a wound is properly cleansed and débrided and kept moist and protected, epithelialization proceeds at a maximum rate.

In a surgically repaired laceration, epithelialization bridges the defect by 48 hours. The new tissue proceeds to thicken and grow downward, beginning to resemble the layered structural characteristics of uninjured epidermis within 5 days. Simultaneously, keratin formation loosens the overlying scab.

Biomechanical Properties of Skin

Various forces (lines of tension) exist as a result of skin elasticity from collagen fibers. These static forces may vary more than five-fold with the respective area of body skin surface, but the static tension of a given area of skin remains constant. These static forces are shown clinically by the gaping of wounds after incision. The magnitude of static skin tension is directly related to ultimate scar width.
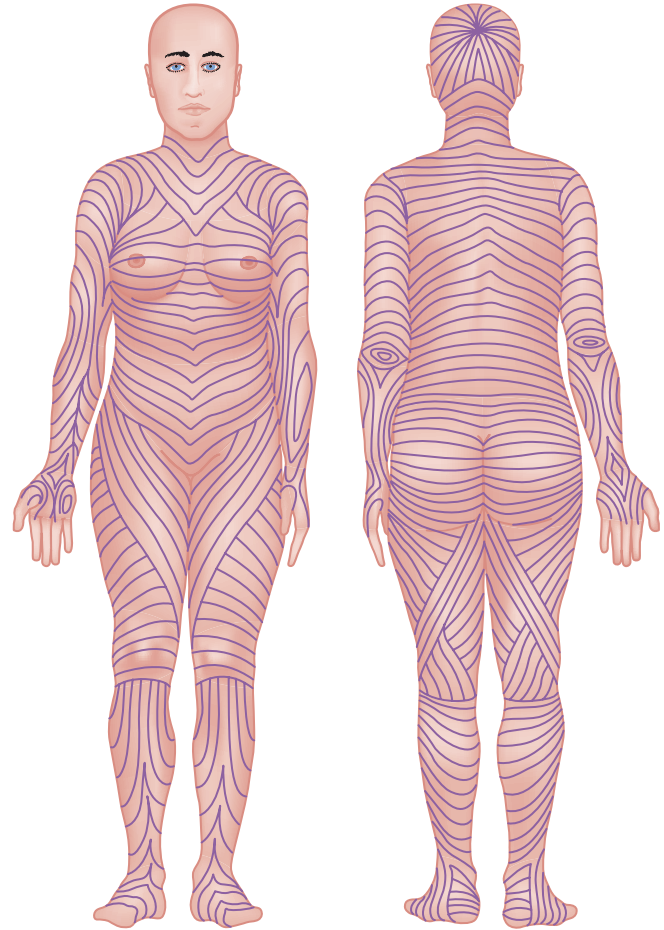
Uneven, jagged wounds have greater surface area than do linear lacerations. The skin tension is distributed over a greater area and is less per unit length of tissue. Meticulous reapproximation of the jagged edges results in a more appealing scar. Sharp débridement, converting a jagged wound to a linear laceration, is often unwise because it may cause too much tissue loss and produce a wider, more visible scar. Skin forces produced by muscular contraction and movements of flexion and extension influence healing and scar size.[1] These dynamic forces are greatest where skin elasticity is necessary for function. Lacerations parallel to skin folds, lines of expression, and joints do not impair function or produce unattractive scars. Wounds that traverse the skin lines heal with conspicuous scars and may impair function. Knowledge of these lines and forces is necessary for optimal wound repair. In addition, the patient should be educated about wound healing and scarring potential.

CLINICAL FEATURES

History

A detailed history should be obtained as part of routine wound evaluation. Serious complications can result when basic information is not obtained. If the patient has significant peripheral vascular disease, is immunocompromised, or has a high risk of a retained foreign body, wound care decisions may be changed. Essential historical information includes past medical history, mechanism and setting of injury, and tetanus status.

BOX 52.1

Risk Factors for Wound Infection

1. Location: Leg and thigh, then arms, then feet, then chest, then back, then face, then scalp
2. Contamination with devitalized tissue, foreign matter, saliva, or stool
3. Blunt (crush) mechanism
4. Presence of subcutaneous sutures
5. Type of repair: Risk greatest with sutures > staples > tape
6. Anesthesia with epinephrine
7. High-velocity missile injuries
8. Diabetes

Risk Factors

Risk factors for wound morbidity include prolonged time since injury; crush mechanism; deep wounds longer than 5 cm; age of the patient; high-velocity missiles; location on lower extremities; and contamination with saliva, feces, soil, or other foreign matter (Box 52.1).Three hours after acute trauma, bacteria proliferate to a level that may result in infection. Standard wound care guidelines for routine wound care recommend closure within 8 to 12 hours of injury yet new data suggests that timing is less important than the other risk factors.[1] All risk factors must be considered to optimize wound care, and flexibility is required. Lacerations produced by fine cutting forces resist infection better than crush injuries. Reduction of blood flow to wound edges in the latter may increase the infective concentration of bacteria by a hundredfold. High-velocity missile injuries produce damage remote from the missile tract. The extent of injury may not be apparent for several days. Clean, finely cut lacerations on the face may be safely closed in some patients 24 or more hours after injury, whereas blunt lacerations to the leg or thigh may be treated with delayed primary closure as early as 4 to 6 hours after injury. For sutured wounds, location appears to have the strongest association with infection. Lacerations repaired on the leg and thigh may have an infection rate greater than 20%, those on the torso and other extremities greater than 10%, and those on the face and scalp less than 4%.

Optimal physical assessment of wounds requires patience, diligence, and an organized approach. Wound closure decisions are individualized for each laceration and each patient. In addition to the acute history, host specific data will influence management decisions: (1) immunocompetence of the host, (2) physical characteristics of the host (eg, peripheral vascular disease), and (3) structural defects that invite bacterial seeding (eg, damaged or prosthetic heart valves).

Physical Examination

Physical examination errors are minimized with optimal visualization and anesthesia. When the injury occurs on an extremity, use of a sphygmomanometer may help to ensure a bloodless field. The blood pressure cuff is placed proximal to the injury, and the extremity is elevated above the heart for at least 1 minute. Exsanguinating the extremity may be hastened by wrapping the limb tightly with an Ace bandage, beginning distally and ending at the base of the cuff. The sphygmomanometer is inflated to a pressure greater than the systolic pressure of the patient. Although this process causes the patient significant discomfort after 1 minute, the cuff can safely remain inflated for 2 hours. Alternatively, a peripheral nerve block or Bier block should be used if inflation longer than several minutes is contemplated.

A thorough examination of the wound requires that the tissues be adequately anesthetized. Subcutaneous tissues quickly reapproximate after injury, giving the appearance of a shallow wound. In addition, significant subcutaneous swelling lends to this appearance and renders examination of the laceration more difficult, as in wounds of the scalp and face. Careful probing and examination are needed to avoid missing damage to structures deep to the skin and subcutaneous tissue. This warning is more crucial for wounds on the distal aspects of upper and lower extremities. Finger lacerations are rarely gaping, but crucial structures (eg, tendons, nerves, and vessels) are often damaged. The examiner must pry the wound margins apart, ensure a blood-free field, and examine the tissues as the digit or extremity is placed through range of motion. The injured section of tendon may have been in a different state of tension and in a more proximal or distal location at the time of injury. Wounds that cannot be explored adequately and wounds with probable trauma to underlying tissues or with foreign matter require additional studies. It may be appropriate to extend the laceration to enable improved visualization of wound depth and extent.

Sterile gloves may not be a necessary part of wound closure. Although data are limited, one study found that the use of sterile gloves makes no difference with respect to the incidence of infection. However, clean nonsterile gloves should be worn to offer some protection for both the patient and the provider.[2]

No single method can guarantee the identification and removal of all foreign matter from wounds. The key is to document all efforts and to explain to the patient the possibility of a foreign body. Physical examination with wound exploration will discover about 78% of foreign bodies; plain radiography will detect glass foreign bodies in about 75% of cases, metal in 99%, and wood in 7%.[3] Good follow-up can protect the patient as well as the health care provider.

DIAGNOSTIC TESTING

As noted earlier, attempts to visualize foreign matter by standard radiography are not as helpful as might be expected. The radiodensity of an object depends on the relative density of the matter and the adjacent tissue. Pieces of glass more than 1 mm thick are visible when appropriate views are ordered. Many organic substances, such as wood, are not visible on plain films, but specifically requested soft tissue views may increase the yield. A radiolucent shadow may be seen on close inspection, because the foreign substance displaces tissue in its path. Xerograms are better than plain radiography but still miss some plastics and organic matter. A computed tomography (CT) scan is excellent for identifying all foreign substances but is expensive and results in exposure to radiation. Ultrasonography is a good technique, but the small size of many foreign bodies and pockets of air, edema, pus, and some calcifications may produce confusing echoes, limiting its clinical usefulness. When simpler, standard methods fail to locate a foreign body that is likely or definitely present, we recommend that ultrasonography or a CT scan should be considered.[3]

MANAGEMENT

Anesthesia

After an appropriate neurovascular examination is documented, the involved tissue should be anesthetized. Careful physical examination and thorough cleansing, irrigation, and débridement require that the patient be free of pain. Regional anesthesia may be preferable for wounds innervated by one superficial nerve. Injections at the wound site produce swelling and further distortion of landmarks. With a regional block, more than one laceration may be repaired in the same nerve distribution without

additional anesthesia. Lacerations on the face, hands, fingers, feet, and toes and in the mouth are often well suited for regional anesthesia.

Anesthetic Agents

Lidocaine (Xylocaine) is the most common agent used for local and regional anesthesia. It is safe and fast acting. Onset of action for direct infiltration occurs within seconds, and the effects last 20 to 60 minutes. When lidocaine is administered as a regional nerve block, onset occurs in 4 to 6 minutes and the effects generally last 75 minutes, although the block may remain effective for 120 minutes. A 1% lidocaine solution contains 10 mg/mL. It is safe to use 3 to 5 mg/kg, not exceeding 300 mg at a single injection. More volume can be added safely every 30 minutes. When epinephrine is added, the resulting vasoconstriction prolongs the effect for 2 to 6 hours, and the safe dose is increased to 5 to 7 mg/kg. However, the addition of epinephrine has been shown to delay healing and lower resistance to infection. Lidocaine with epinephrine should be avoided in wounds with higher risks of infection and when tissue viability is of concern. Traditional teaching has been to avoid epinephrine in the fingers and toes because of the risk of vasoconstriction in small arterioles. However, recent literature suggests that with careful screening, epinephrine can be safely used in digital blocks. Digital artery vasospasm, accidentally induced by local injection of epinephrine, can be reversed successfully with a local injection of 0.5 to 2 mg of subcutaneous phentolamine or application of topical nitroglycerin.

Bupivacaine (Marcaine) provides anesthesia that is equal to that of lidocaine. Onset of action is slightly slower than that of lidocaine, but the duration of anesthesia is four to eight times longer.[4] These benefits suggest that bupivacaine is the preferred local anesthetic agent for the care of most wounds. In adults, the maximal reported safe dose is approximately 2.5 mg/kg without epinephrine and 3.5 mg/kg with epinephrine. The dose can be repeated every 3 hours, not exceeding a total of more than 400 mg in a 24-hour period. The maximal intraoral dose is 90 mg.

Local injection of lidocaine should be done with a 27-gauge needle; the slower the injection, the less pain produced. The rate of injection through a 30-gauge needle is far too slow, and the thin needle is difficult to control. A 25-gauge needle is acceptable, but the more rapid injection can result in greater patient discomfort. The needle should be introduced through the cut margin to minimize the pain of the injection. Concerns of spreading bacteria into the adjacent uninvolved tissue and increasing the frequency and severity of wound infections are unfounded. The pain of injecting lidocaine can be ameliorated with the addition of bicarbonate to buffer the solution. The shelf life of the lidocaine-bicarbonate mixture decreases, but it remains effective for 1 week at room temperature and for 2 weeks if refrigerated. Adding sodium bicarbonate in a 1:10 volume ratio to lidocaine (1 mL bicarbonate and 10 mL lidocaine) decreases the pain of injection without compromising the quality of anesthesia. A much smaller dose of bicarbonate is added to bupivacaine because the alkalinization results in precipitation. A 1:100 volume ratio (0.1 mL of bicarbonate and 10 mL of bupivacaine) has been found to be effective. Warming the anesthetic solution is also an effective means of decreasing the pain of injection.

Topical anesthesia may be an effective painless alternative. Studies show that a combination of lidocaine (4%), epinephrine (0.1%), and tetracaine (0.5%) (LET) can function effectively on skin lacerations, especially on the face and scalp.[20,21] LET may be administered by soaking a cotton ball with 3 mL of the combined solution and applying it to the wound for 20 minutes. A gel formulation is available and may be preferred, because it's easier to control and to limit run off and inadvertent contact with mucous membranes. The duration of action is 45 to 60 minutes following the removal of the gel from the wound. Toxicity is rare when the dose administered is no more than 3 cc and mucous membranes are avoided. Potential toxic effects of lidocaine and tetracaine are related to the cardiovascular and central nervous systems. Cardiovascular effects may include arrhythmia, ectopy, decreased contractility, and cardiac arrest. Central nervous system toxicity may include headache, irritability, restlessness, blurred vision, and seizures. With use of a topical anesthetic, time to repair is reduced, patient acceptance improves, and landmarks are left undisturbed. If additional anesthesia is required, the pain of the subsequent injection is lessened by the topical anesthesia.[5]

Although LET has been found to be very safe, weight-based dosing has been recommended for children weighing less than 17 kg. Adminstering a maximum of 0.175 mL/kg of LET will prevent the application of more than 5 mg/kg of lidocaine. No cases of methemoglobinemia have been reported, but given the small risk associated with tetracaine extra caution is advised in neonates.

Tetracaine, adrenaline (epinephrine), and cocaine (TAC) was the original topical anesthetic solution. This combination is as effective as LET on the face and scalp and more effective elsewhere on the body. However, the risk of complications is greater, and the complexities tied to the handling of cocaine limits its utility.

Eutectic mixture of local anesthetics (EMLA) is a cream used to produce anesthesia of wounds and intact skin. The active ingredients are lidocaine (2.5%) and prilocaine (2.5%). The micronsized particles of the cream are designed to penetrate layers of the skin to lessen the pain of needle penetration. Studies have demonstrated efficacy in venipuncture, immunization administration, lumbar puncture, and laceration repair. Peak effect requires about 1 hour and continues for 30 to 60 minutes after removal of the cream.

Allergy

Allergy to local anesthetics is uncommon. Two distinct groups of "caine" anesthetics exist. The esters include procaine, tetracaine, and benzocaine. The second group, including lidocaine and bupivacaine, belong to the amide family. Allergy to the esters is uncommon. True allergy to agents in the amide family is rare.

The subject of allergy is complicated further, because multidose vials contain the preservative methylparaben, an ester related structurally to anesthetics in the ester family. Apparent allergic reaction to lidocaine or bupivacaine may be a reaction to the methylparaben. Single dose, preservative free, vials of lidocaine and bupivacaine should be standard stock in every emergency department (ED).

When allergy to a local anesthetic is known or strongly suspected, alternatives are available. No cross-reactivity occurs between the amide and ester families, so an agent from a different group may be chosen. A test dose of 0.1 mL may be administered intradermally before proceeding. The patient should be observed for 30 minutes, and as with any allergy testing, the emergency clinician should be prepared to treat all complications. Aqueous diphenhydramine (1%) has also been shown to provide effective local anesthesia.

Skin Preparation

Disinfection of the skin (not the wound itself) may be accomplished with several different agents. The ideal agent is fast acting, has a broad spectrum of antimicrobial activity, and has a long shelf life. Povidone-iodine (Betadine) and chlorhexidine (Hibiclens) have all three characteristics. Although excellent as skin disinfectants, both products are toxic to wound defenses and may increase the incidence of wound infection. Povidone-iodine is effective against gram-positive and gram-negative bacteria, fungi,

and viruses. Chlorhexidine is less effective against gram-negative bacteria, and its efficacy against viruses is unknown. Care must be taken to avoid spilling these substances into the wound. Exposure of the eye to these agents can be detrimental. Chlorhexidine has been shown experimentally and in case reports to produce serious permanent corneal opacification. Current data suggests that chlorhexidine-alcohol preparations are safe and more effective at limiting infection compared with povidone-iodine solutions.[6,7]

Body, facial, and head hair is usually removed to clean and examine the wound, although this is not necessary to diminish the risk of wound infection. Removal of the hair makes it easier for the patient to keep the area clean and ultimately facilitates accurate suture placement and removal. Exceptions are parts of the body where hairlines provide important landmarks for the accurate reapproximation of tissue margins, most notably the eyebrow. Reports of inconsistent or absent eyebrow hair regrowth suggest that eyebrow hair should not be shaved.

Surgical studies show that hair removal with a razor is three to nine times more likely to result in a wound infection than clipping the hair. It seems that the razor damages the infundibulum of the hair follicle. The wounded follicle provides access for bacterial invasion and ultimately infection. For wounds considered to be at high risk of infection, clipping may be done with electronic shears or scissors. Another option is to apply a petroleum-based product to the hair adjacent to the wound margins, allowing the provider to keep the hair away from the surgical field.

Wound Preparation

Débridement

Débridement is the removal of foreign matter and devitalized tissue from the wound. With respect to ultimate wound healing and risk of infection, débridement is the most important consideration in wound care. The presence of any devitalized tissue in the wound delays healing and significantly increases the risk of infection. However, the benefits of débridement have to be weighed against the consequences of producing a larger tissue defect. The resultant closure is exposed to higher tension and may result in a wider scar. Skin edges that are clearly devitalized are débrided before wound closure. On the trunk, where there is little concern for specialized tissue, wide excision and débridement are feasible. On the face and hands, where all tissue must be saved if possible, the process is more difficult. Meticulous sharp excision of small fragments of nonviable tissue should be performed only by experienced physicians. When the viability of large areas of skin or muscle is a significant concern, the wound should be prepared for delayed primary closure.

Wound Cleansing

An ideal wound cleanser has broad antimicrobial activity with a rapid onset. It is nontoxic to the tissue and does not reduce tissue resistance to infection, delay healing, or decrease the tensile strength of the healing wound. Many antiseptic solutions have been used clinically and studied in great detail. Much debate exists regarding which agent comes closest to possessing these qualities. Povidone-iodine in various concentrations, saline, and, more recently, tap water have received the most attention.

Evidence suggests that a 0.9% normal saline solution or tap water are effective irrigants when used with high-pressure syringe irrigation. Saline is the traditional wound-irrigating fluid of choice. However, tap water has consistently produced equivalent rates of infection and cosmetic outcomes. Tap water irrigation allows a large volume of irrigation rapidly and inexpensively and is especially suited to upper extremity and scalp injuries.[8]

Free iodine, although possessing broad, rapid antimicrobial activity, is too toxic to tissue and its defenses to have therapeutic value in the open wound. Iodophor is a complex of iodine with a carrier to increase its solubility and decrease the availability of free iodine. The most widely used iodophor is povidone-iodine, in which the carrier molecule is povidone (formerly polyvinylpyrrolidone). It is generally available in a 10% solution, which is 1% free iodine. It is well documented that even a 5% povidone-iodine solution is toxic to polymorphonuclear neutrophil leukocyte activity and may increase the infection rate. A 1% solution is safe and effective with little or no toxicity. Detergent-containing cleansers, such as povidone-iodine scrub, may be excellent for skin preparation but are toxic to tissue defenses and should never be allowed to contaminate open wounds.

Although many different irrigation solutions may be beneficial, it seems that the key to cleansing is high-pressure irrigation rather than the type of solution used. Tap water irrigation soon may become the preferred method of irrigation, because it is safe, is effective, requires no preparation, and is less expensive.

Irrigation

The quality of mechanical cleansing is one of the most important determinants of wound prognosis. The most effective form of wound cleansing is high-pressure irrigation. Irrigating with pressures greater than 7 pounds per square inch (psi) significantly decreases the number of bacteria and the incidence of infection. Although several commercial devices are available, attaching an 18-gauge needle to a 35-mL syringe yields a force of 7 or 8 psi. High pressures of 50 to 70 psi may be obtained with a commercial water pick. These pressures may cause some tissue damage, but the beneficial effect of ridding the wound of bacteria and debris outweighs this risk. Simply soaking the wound in an antiseptic solution is not beneficial and may be harmful. Scrubbing the wound with a sponge with large-pore cells inflicts tissue trauma and impairs the ability to resist infection. Tissue damage can be decreased by use of a sponge with a fine size of pore cell. Adding a surfactant further minimizes the mechanical trauma inflicted by the sponge. Flooding the wound under low pressure via a bulb syringe or gravity alone does not reduce the incidence of infection, regardless of the agent used.

At least one study has shown little benefit to any irrigation in facial and scalp lacerations. This study prospectively compared outcomes of almost 2000 immunocompetent patients. Infection rates and cosmetic outcomes were similar in the irrigation and the non-irrigation groups. We recommend irrigation only for scalp wounds more than 5 cm long and those with other high risk features.

Wound Closure

Decision-Making

The first determination required is whether the wound should be treated open or closed. Each wound, patient, and clinical circumstance must be handled individually. As discussed in the Risk Factors section, most wounds have a low risk of infection and can safely be closed primarily. A small study from Europe failed to show a difference in infection risk for wounds sutured more than 6 hours after injury.[9] At the other end of the spectrum, some wounds must never be closed at the time of their initial ED visit. A large stellate laceration to the foot produced by blunt force and contaminated with dirt and grease must be cleaned and left open to be closed later. Human and animal bites to the hand are additional examples of wound that should not be closed primarily. Physician judgment is often the best method for deciding when it is safe to close a wound. In one study in which hand wounds were

described as dirty, 22% became infected. When the injury was documented to be clean, the incidence of infection was 7.1%.

Three wound closure options are available. The wound may be (1) closed primarily in traditional fashion, (2) closed in 4 or 5 days (delayed primary closure), or (3) left open and allowed to heal on its own. Delayed primary closure is a safe alternative to traditional primary closure. Overall healing time is not affected, and the risk of infection is greatly decreased if proper technique is used. When a wound is slated for delayed primary closure, it is prepared, débrided, and irrigated in the same manner as for immediate closure. The wound should be packed to prevent it from closing on its own. If the wound is on an extremity, the injury should be splinted and dressed, and appropriate wound care instructions should be given. The patient should return for a wound check and packing change in 24 hours and should be instructed to follow up in another 72 hours for definitive repair, with wound closure undertaken 96 to 120 hours after injury. No studies offer guidelines for prophylactic antibiotic use when delayed primary closure is the treatment option. Extrapolation from other wound studies strongly suggests that antibiotics offer no benefit.

Individuals who do not seek medical care after an injury select the option of leaving a wound open to heal on its own. Most patients who visit an ED with a laceration undergo some form of wound closure. Yet one study that examined unsutured hand lacerations less than 2 cm long followed patients for 3 months and found that there was no significant difference in cosmetic appearance, and there was no difference in time to resumption of activities of daily living.

Closing a wound loosely is occasionally discussed as an option in the treatment of contaminated wounds. This choice should rarely be considered. The loosely closed wound approximates the tissue margins enough to allow the wound to seal itself completely within 48 hours. The infection risk when this method is used is the same as when the wound is closed traditionally.

Wound Tension

The goal of wound closure is optimal anatomic and functional reapproximation of tissue with minimal risk of complication. Consideration must be given to the wound's size, shape, location, depth, and degree of tension. Wounds with high static and dynamic tension that require meticulous closure cannot be closed with tape or staples. Delicate approximation of wound edges under tension can be accomplished only with suture.

Several techniques may be used to reduce wound tension. Deep sutures may be placed in subcutaneous tissue to help bring the wound margins closer together. In this manner, forces on the skin are reduced, and potential dead space can be closed. Care should be taken to avoid suturing adipose tissue, because it may become necrotic, increasing the likelihood of infection. The number of dermal sutures depends on the characteristics of the wound. In general, the number should be kept to a minimum, because suture material acts as foreign matter in the wound and can increase the risk of infection. Subcutaneous sutures should never be placed in the hand or foot because of the major structures that reside near the surface. Another method of ameliorating static tension from cut edges of the wound is to undermine at the lacerated margin. Undermining helps free the dermis from its deeper attachments, allowing the skin edges to be approximated with less force. Care must be taken to preserve the blood supply to the wound margins and not increase dead space in the process.

Suture Technique

Careful surgical technique is important to optimize the ultimate repair. If possible, pickups, hemostats, or forceps should not be used, especially on wound margins. Blind clamping in a wound can damage a nerve, artery, or tendon. Wound margins should be everted and the sutures tied just tightly enough to allow the edges to approximate lightly. The edges can be everted by ensuring that the needle enters and exits perpendicular to the skin. Wounds with opposing margins of different thickness can be difficult to close. If this difference is not considered and corrected, the ultimate scar has uneven margins that cast a shadow on the skin and is unsightly. In closing these wounds, the needle should be pulled through the cut margin of one side before entering the opposite edge. This method gives the emergency clinician the best opportunity to take an equivalent amount of tissue on both sides of the wound. Viable edges of a jagged wound must be meticulously reapproximated. Because of the greater surface area and the ultimate contraction of the wound, preserving the jagged edges results in a more "natural" scar.

Most lacerations are closed with running or interrupted percutaneous suture. The running technique is appropriate for linear lacerations under minimal tension when there is a low risk of infection. This technique is more rapid, requires less suture material, and yields equivalent cosmetic results. Curvilinear or jagged wounds are best closed with interrupted sutures to distribute tension properly. Because tensile strength of interrupted sutures may be superior, wound edges subjected to higher levels of tension should be closed with interrupted sutures.

Basic and Advanced Techniques

Simple Sutures. Wound closure with simple interrupted sutures is the most common method of laceration repair in the ED. The placement of simple sutures yields excellent cosmesis and a low infection rate.

Procedure. The needle is placed to one side of the laceration margin and enters the skin at approximately 90 degrees. To pass the needle through the tissue, the clinician supinates his or her wrist and guides the needle deep but parallel to the skin surface. Wrist supination is extended as the needle exits the skin on the opposite side perpendicular to the surface. Proper technique produces wound edges that are slightly everted and are lightly touching. The art of the process takes into consideration swelling while being careful not to secure the suture too tightly, because necrosis of the wound margin tissue can seriously compromise healing.

Intradermal (Buried) Sutures. Placing cutaneous sutures in wounds under tension can lead to ischemia of the wound margin and an unsightly scar. Proper placement of buried intradermal sutures helps to approximate dermal margins and reduce wound edge tension. Buried sutures should not be used in contaminated wounds, because they increase the risk of wound infection. Sutures through adipose tissue also increase infection and do not relieve skin tension.

Procedure. Placement of buried sutures differs from traditional suturing because of the need to bury the knot deep to the skin. Failure to do this can interfere with dermal healing and can leave a small lump under the surface of the skin. The needle is introduced deep in the wound in the subcutaneous tissue and emerges from the dermis below the skin surface. The needle is reintroduced in the dermis on the opposite wound margin and emerges from the subcutaneous tissue at the same level on the opposite side. The knot is secured and remains buried deep below the skin surface.

Scalp Laceration Repair. In contrast to small lacerations elsewhere on the body, most scalp lacerations require repair because of the propensity to bleed profusely. The dense connective tissue beneath the skin tends to hold vessels open and delay hemostasis. Frontal scalp lacerations in young men should be considered to be a cosmetically significant wound. Although the scalp
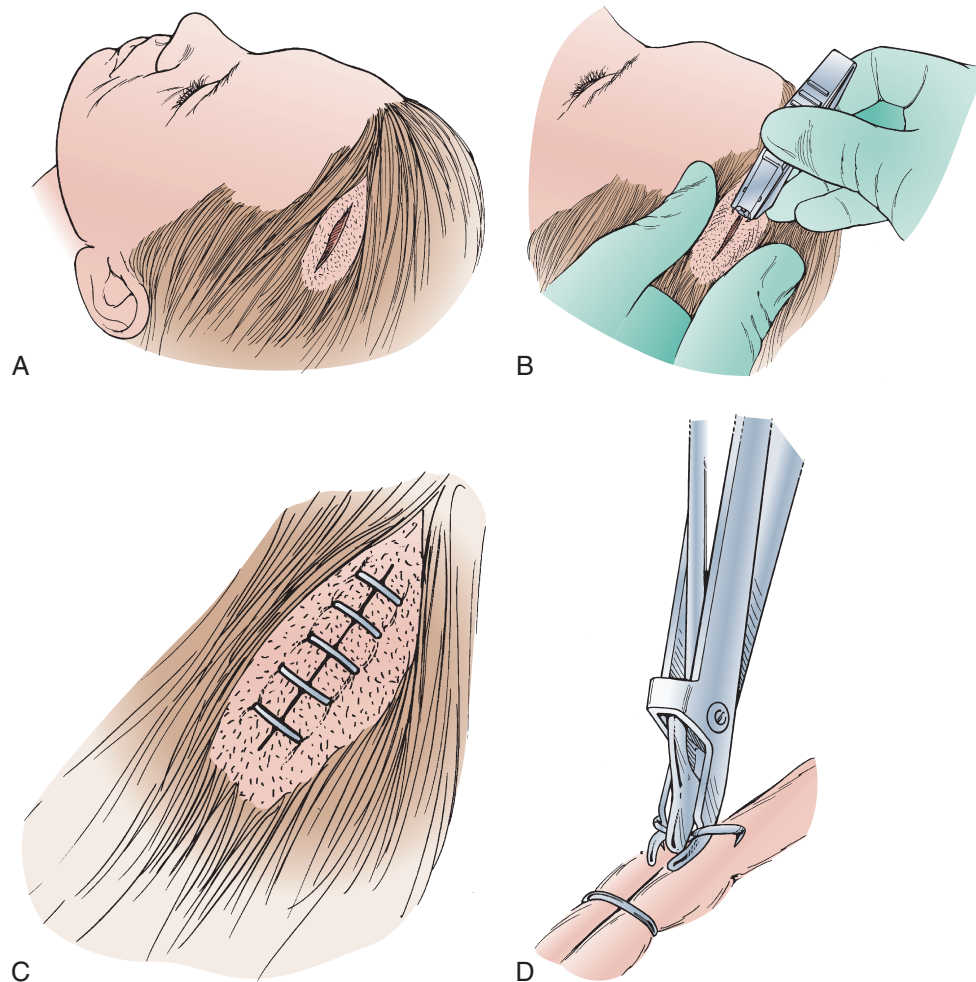
Fig. 52.3. **A** to **D,** Scalp laceration repair. (Adapted from Simon BC: Skin and subcutaneous tissue. In Rosen P, et al, editors: Atlas of emergency procedures, St Louis, 2001, Mosby.)

laceration currently may be well hidden by hair, most men experience some balding. Care must be taken to explore the laceration thoroughly to look for a defect in the galea, an injury that requires repair with deep sutures. Staples may be ideal for the skin closure of simple linear scalp lacerations. Hair is less of a problem in placing staples, staples can be placed more quickly than traditional suture, and staples are easier to see and can be removed 1 to 3 days earlier than traditional sutures (Fig. 52.3). Staples may produce artifact on CT scans, but useful information may still be obtained if CT is necessary. Staples may move during magnetic resonance imaging (MRI) and should not be placed if this imaging modality is being considered. Lightweight stapling devices are available. Most devices come preloaded with five or more staples and are easy to use. Hair apposition may also be an option for the closure of many scalp wounds. The technique involves grabbing a bundle of hair on both sides of the wound and then twisting the hair bundles with a hemostat. A small dab of cyanoacrylate glue is applied to the twisted hair to prevent unraveling. Patient satisfaction is high with this approach.[10]

Traditional sutures are used to repair most scalp lacerations, usually with standard nylon suture. Absorbable chromic gut can be used in children and in adults who may not return for suture removal.

Procedure. Anesthesia with epinephrine is recommended to help control bleeding. Hair removal is necessary only if the hair makes closure difficult. A defect in the galea is closed with 3-0 or 4-0 absorbable suture. Failure to repair the galea can lead to a cosmetic deformity related to frontalis muscle function. Linear superficial scalp lacerations that do not require deep sutures can be closed with staples or with monofilament nylon sutures applied with a simple interrupted or running technique. Jagged or macerated lacerations may require some débridement and horizontal mattress sutures. When one chooses to staple a scalp laceration, the adjacent skin margins are pinched together with forceps to evert wound margins. The "mouth" of the stapler is placed gently on the skin surface, taking care not to indent the skin. The handle of the stapler is squeezed carefully to eject the staple into the tissue. Ideally, the staple closely approximates the wound margins without indenting the surface of the skin. For release of the staple, the wrist is pulled back to disengage itself from the last staple.

Vigorously bleeding scalp lacerations often need temporizing measures to control bleeding while the patient is being evaluated and resuscitated. An anesthetic agent with epinephrine should be used and may be helpful to control some bleeding. Blindly clamping in an attempt to control bleeding is unwise and not likely to be successful. Raney scalp clips can be rapidly applied to the wound margins to quickly gain control of the bleeding. An applicator is used to apply and remove the clips so that they can be replaced with sutures once the patient has been stabilized. The clips are plastic and will not interfere with CT or MRI.

Staple removal is simple, especially if the patient has kept the wound clean and free of dried secretions. The dual prongs on the

disposable staple remover slide under the staple crossbar. As the handle is squeezed and the horizontal aspect of the staple is depressed, the sharp edges are eased out of the tissue for removal.

Skin Tears. Most commonly seen in the elderly and chronically ill, skin tears can be a treatment dilemma for emergency clinicians. These tears are a result of shearing forces that separate the epidermis from the underlying dermal layer of the skin. Often the result of minor trauma, these injuries may be minor tears or as large gaping wounds with extensive loss of tissue. Approximating the wound margins by aligning thin fragile tissue can be very difficult. Studies have confirmed that the use of Steri-Strips and or topical skin adhesives (cyanoacrylate-based derivatives; see later) is currently the preferred option. Either material may be used alone; however, when tension exists, placing the Steri-Strips first, then the adhesive, may be the optimal approach. Care must be taken in deciding what type of dressing to use. Transparent films can cause fluid to collect and delay healing. Adhesives are difficult to remove and can cause additional tearing. If the wound must be covered, then hydrogel sheets, hydrocolloid dressings, or both are recommended.[11]

Vertical Mattress Sutures. Vertical mattress sutures improve wound edge eversion. They are also used for the closure of gaping wounds and deep lacerations that may need more than simple sutures to close potential dead space. Areas of lax skin tension, generally where maximal skin mobility is needed (such

as, over joint surfaces), may need assistance to ensure eversion of the wound margins. Vertical mattress sutures may be ideal to accomplish both tasks.

Procedure. A vertical mattress suture is a combination of deep and superficial components. The needle is introduced at a 90-degree angle approximately 1 cm from the wound margin. The needle courses through the depth of the wound and emerges on the opposite side, 1 cm from the laceration margin at a 90-degree angle. The needle is reintroduced 1 or 2 mm from the epidermal edge for final approximation of the wound.

Horizontal Mattress Sutures. Horizontal mattress sutures are useful to help disperse excess skin tension and to evert wound edges. The scalp, which has minimal skin mobility, is one area where gaping lacerations may benefit from this tension-reduction method. Horizontal mattress sutures may also be beneficial in thin, fragile skin of elderly people and for lacerations that have lost tissue from the injury or débridement.

Procedure. The initial step is to pass the needle as for a simple interrupted stitch (Fig. 52.4). On exiting the skin, however, the needle is reintroduced approximately 0.5 cm adjacent to the exit point. This second "bite" reemerges 0.5 cm adjacent to the initial insertion point and is tied. Unlike with vertical mattress sutures, each bite is always the same distance from the wound margin.

Dog-Ear Deformity Repair. Some redundant tissue may result on one side of the repair as the closure nears completion,
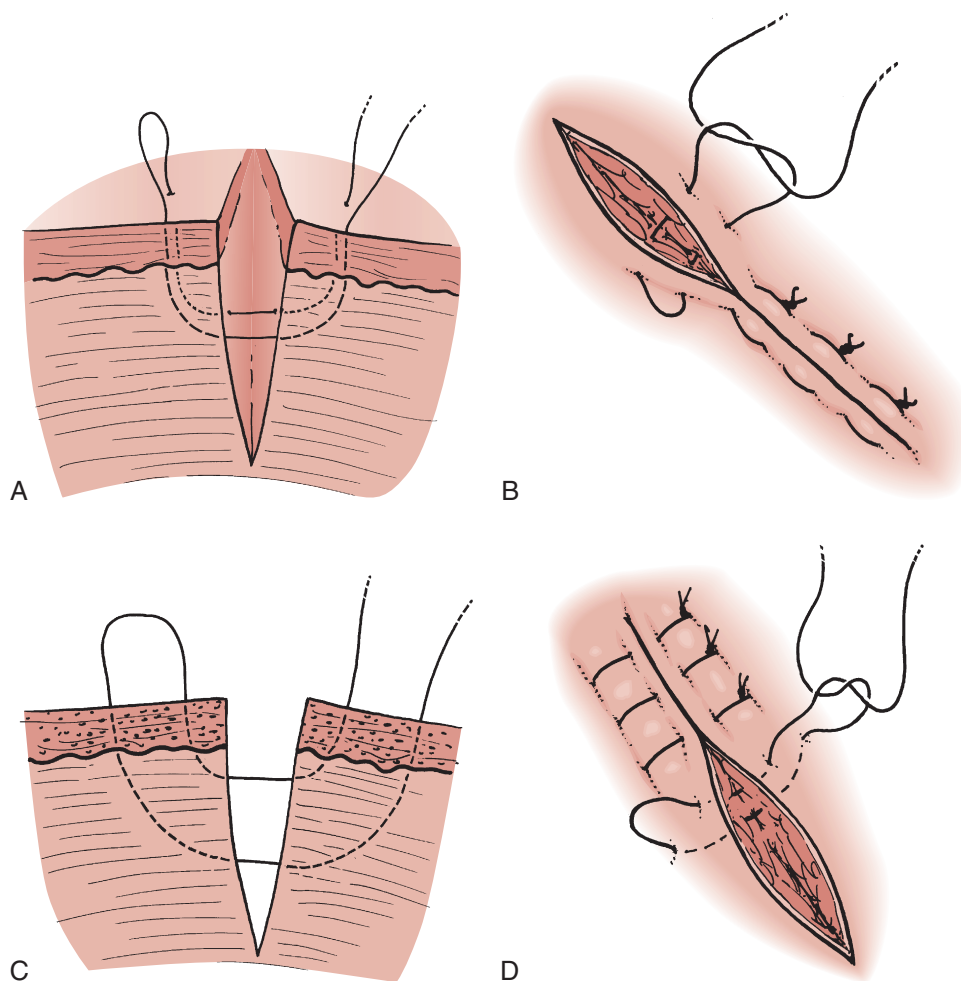

Fig. 52.4. A to **D,** Mattress suture. (Adapted from Simon BC: Skin and subcutaneous tissue. In Rosen P, et al, editors: Atlas of emergency procedures, St Louis, 2001, Mosby.)

especially in the closure of curvilinear lacerations. This redundant tissue generally can be avoided by placing the initial suture in the middle of a curvilinear wound. If the clinician has limited experience, excision and undermining of tissue are likely to result in complications and should not be attempted.

Procedure. The laceration repair begins in a traditional manner and continues to approximately the final 1 cm of the wound (Fig. 52.5). A short incision (approximately 1 cm) is made from the end of the laceration at a 45-degree angle. The angle is cut toward the side of the redundant, bunched tissue. In most cases, the subcutaneous tissue from the start of the dog-ear defect to the newly created end of the wound must be gently undermined to mobilize the skin. The next step, the final step before suturing, is the most important. The work that has just been completed leaves a small triangular piece of excess tissue. The redundant piece is gently lifted with the tissue forceps and excised in a line parallel to the incision made above. The wound can now be closed with simple interrupted suture technique.

Corner Stitch (Half-Buried Horizontal Mattress Sutures). Jagged and triangular wounds create corners that can be difficult to repair. The clinician must avoid placing the suture directly in the tip of the flap. This practice may "stretch" the tissue and further compromise blood flow to the wound margin. The corner stitch allows optimal tissue approximation with minimal tension.

Procedure. The needle is introduced percutaneously through the non-flap side of the wound a few millimeters from the corner of the wound (Fig. 52.6). The needle is passed horizontally through the dermis of the flap. The final step is to pass the needle into the dermis of the non-flap aspect of the wound a few millimeters from the opposite side of the corner. The suture is led out
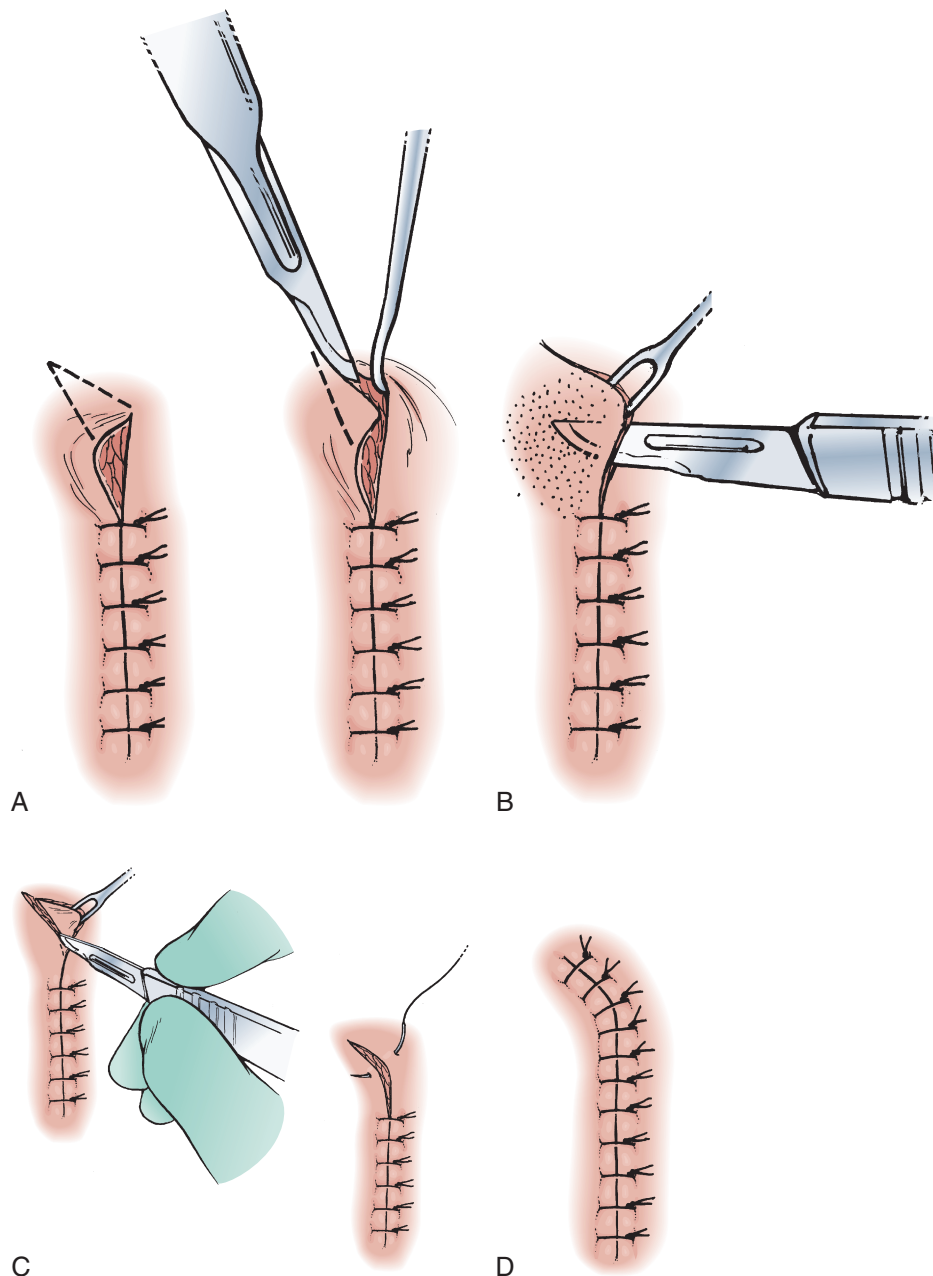

A   B

C   D

Fig. 52.5. **A** to **D,** Dog-ear repair. (Adapted from Simon BC: Skin and subcutaneous tissue. In Rosen P, et al, editors: Atlas of emergency procedures, St Louis, 2001, Mosby.)
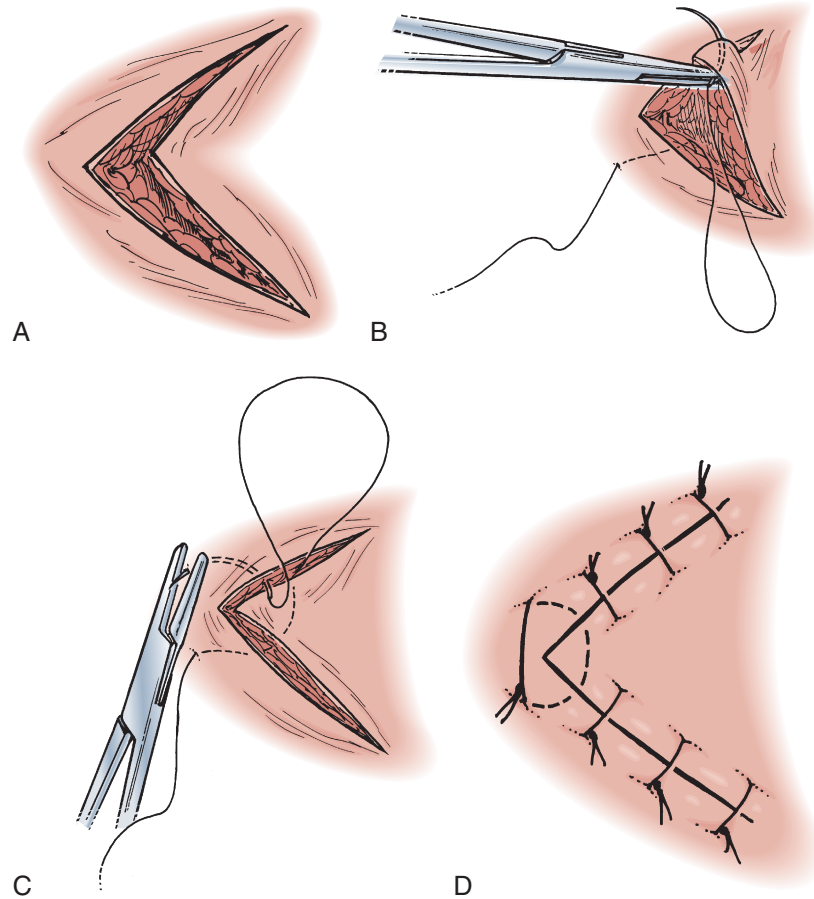
Fig. 52.6. **A** to **D,** Corner stitch (half-buried horizontal mattress). (Adapted from Simon BC: Skin and subcutaneous tissue. In Rosen P, et al, editors: Atlas of emergency procedures, St Louis, 2001, Mosby.)

through the epidermis and tied. This technique can also be used to encompass multiple flaps either individually or simultaneously if the tips are adjacent to one another. The most difficult but important aspect of the corner stitch is to take bites of equal depth with each pass of the needle. Failure to take equal bites of tissue results in a wound with opposing sides that do not lie flat; this leads to a more obvious scar. When the corner has been repaired, the remaining two sides of the wound may be closed with simple interrupted or running suture technique.

V-Y Wound Closure. The V-Y closure is indicated for the repair of V-shaped wounds with tissue loss or with nonviable margins that must be trimmed. The tissue loss is such that the adjacent mobile tissue is not sufficient to close the remaining defect.

Procedure. Nonviable tissue is trimmed with fine iris scissors (Fig. 52.7). The long V-shaped portion of the wound is sutured with simple interrupted percutaneous stitches. This first step brings the tip of the flap closer to the newly created corner of the wound. A corner stitch is used to secure the tip of the flap. The remaining limbs of the Y can be repaired with simple interrupted stitches. Some degree of undermining is likely to be needed to mobilize tissue to close the defect. Débridement of too much tissue can make the final repair more difficult and can distort adjacent anatomy.

Materials

In the Middle Ages and earlier, materials used to close wounds included flax, hemp, fascia, hair, linen strips, pigs' bristles, reeds,

grasses, and even the mouth parts of the pincher ant. In the early 1900s, natural organic protein products, including silk, cotton, and catgut, were the only available substances. Polyester (Dacron) and nylon were the first synthetic materials, available in the 1940s. Since then, a host of other synthetic materials have become available.

Suture. The ideal suture is inert to metabolism, is resistant to infection, has great tensile strength, does not tear tissue, is easy to work with and tie, and is available in convenient colors with a variety of cutting and noncutting needles. A common classification of suture material relies on relative *absorbability.* In general, the materials that maintain their tensile strength for more than 60 days after implantation have been defined as *nonabsorbable.* Materials that undergo rapid degradation in tissue and lose their strength in less than 60 days are considered *absorbable.* A second classification considers the source and nature of the material. *Biologic* substances, which include catgut, collagen, silk, linen, and cotton, generally produce the greatest tissue reaction and have the lowest relative tensile strength but have good knot security. These characteristics are in contrast to *synthetic* materials, such as polyester (Dacron), polyamide (nylon), polypropylene (Prolene), polyglycolide and polylactide polymers (Dexon and Vicryl), polydioxanone (PDS), and steel, which usually have less tissue reactivity, greater strength, and less knot security.

Knotting properties and handling characteristics tend to vary inversely. Knot security is of particular importance in maintaining wound closure and the patient's confidence in the physician. Sutures with smooth or slippery surfaces produce little friction and glide effortlessly through tissue and are easy to tie. Smoother
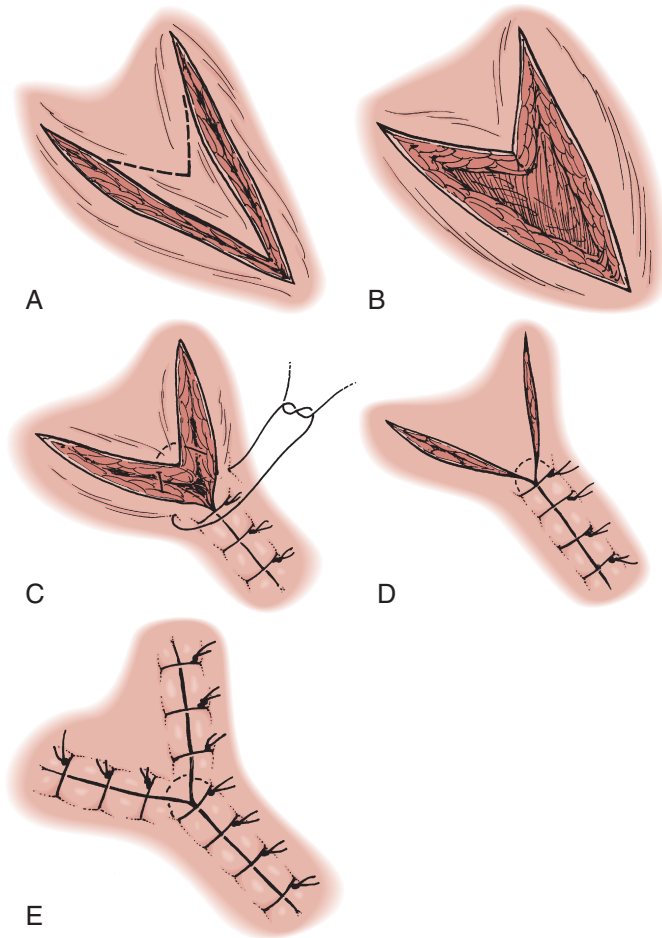
Fig. 52.7. **A** to **E,** V-Y closure. (Adapted from Simon BC: Skin and subcutaneous tissue. In Rosen P, et al, editors: Atlas of emergency procedures, St Louis, 2001, Mosby.)

materials are more difficult to handle and more likely to untie spontaneously. Certain monofilament synthetic materials tend to return or spring back to their original shape. To overcome this suture memory, the first part of the tie should be a "double throw" pulled tightly enough to approximate the tissue, with care taken not to strangulate the margins. The second throw locks the tension of the first part into position. A third throw is used for added security. If this is done properly, additional knotting is not needed after the third throw.

The presence of any suture material in a wound increases the likelihood of infection. Subcutaneous sutures bear the greatest risk. The degree of risk depends on characteristics of the substances used. Braided multifilament materials, such as the polyesters, polyamides, polyglycolides, and silk, yield the highest infection rates, whereas monofilament synthetic substances have the lowest risk of infection. There are several nonabsorbable monofilament synthetic sutures and one absorbable monofilament (PDS). The degree of infectivity of PDS compares well with the low rates of infectivity of similar materials.

Consideration of patient comfort in suture selection is important. Although silk is highly reactive, it ties well, is easy to handle, and is comfortable for the patient. It is an excellent choice for use in and around the lips, where comfort is a major concern. PDS is a comfortable absorbable suture and can be left in intraoral mucosa to be absorbed, with apparently low risks of infection, or it can be removed in 5 to 7 days. Staples or metallic sutures are excellent when strength is needed, but they may be uncomfortable for the patient. Nylon and polypropylene, which are the most

common sutures used on skin, produce little tissue reaction and offer good tensile strength. They tend to be stiff, produce discomfort near the lips, have poor knot security, and may be difficult to work with. A braided, coated polyester nonabsorbable material, such as Ethibond, is easier to work with and has better knot stability. Although Ethibond is more expensive than nylon, its characteristics and added patient comfort suggest that it may be preferable. Absorbable suture materials, such as polyglycolide and polylactide polymers (Dexon and Vicryl), have been used strictly for subcutaneous and mucosal closures. Their highly reactive nature allows them to be broken down and absorbed over weeks. Chromic catgut, another absorbable material, has been shown to be safe and effective for the closure of scalp wounds in children.

Needles. Surgical needles are available in a variety of sizes and shapes with myriad other characteristics. Cutting needles may be reverse cutting, conventional cutting, taper cut, or precision point. Most emergency wounds may be closed with a conventional cutting needle. In addition to its sharp point, it has two opposing cutting edges, with a third on the inside curve. Precision point needles are similarly shaped but are honed 24 extra times and maintain their added sharpness longer. These needles are used for delicate plastic or cosmetic surgery. Noncutting needles are reserved for organ repair and subcutaneous suturing. Cutting needles may also be used to repair subcutaneous tissue. Needle nomenclature is confusing and varies by manufacturer.

Tape. Tape closure may be superior to closure with sutures and staples if applied in the appropriate circumstances. In general, the laceration should be linear and subjected to weak static and dynamic forces. Tape is not considered for wounds requiring meticulous tissue approximation. Compared with other closure materials, tape is associated with lower risk of infection, less expense, and less physician time. In addition, a painful injection of local anesthetic is not needed.

The ideal wound closure tape allows water and gas exchange and possesses elasticity, strength, and optimal adhesiveness. For adhesive properties to be maximized, tincture of benzoin should be painted on the skin adjacent to the wound. Care must be taken to avoid introducing benzoin compound in the wound. A nonwoven, microporous tape, which is not reinforced, has been found to best meet these requirements.

Staples. Staples offer several advantages over sutures. Monofilament stainless steel staples offer less risk of infection than even the least reactive suture.[49] The time necessary to accomplish closure may be significantly lessened. Acceptable wounds must be linear and subjected to weak skin forces. Wounds requiring accurate approximation of tissue are not candidates for staple closure. Staples are also uncomfortable while in situ and on removal. Stapled wounds gain tensile strength sooner, and the staples can be removed 1 to 3 days earlier than sutures. After removal, the staples should be replaced with wound closure tape for continued reinforcement.

Various stapling devices are available. The device must allow good visual access and flexible positioning for difficult angles. A pre-cocking mechanism is necessary to allow the physician to hold the staple securely during its placement. The angle of staple delivery is important. One brand releases the staple perpendicular to the wound with its crossbar flush with the skin; this can result in cross-hatching on the skin or tissue strangulation if placed too deeply. The device needs an ejector spring for smooth staple release and must be able to be handled without producing fatigue.

Tissue Adhesives. European and Canadian physicians have used tissue adhesives (butyl-2-cyanoacrylates) for many years. In 1998, octyl-2-cyanoacrylates were approved for use in the United

States. Tissue adhesives offer many advantages over traditional sutures. The emergency clinician can apply the adhesive quickly and easily with a minimum of patient discomfort. In addition, suture removal in 7 to 10 days is unnecessary, because the adhesive sloughs off the skin in approximately the same amount of time. Evidence indicates that adhesives not only provide their own dressing but also have antibacterial properties and may decrease the rate of wound infections. Closing wounds with adhesives is less expensive than traditional suturing and carries no risk of needle-stick injuries.

Tissue adhesives achieved cosmetic results similar to those of traditional sutures in randomized trials. Tissue adhesive may be applied in high-tension areas, but only if used in conjunction with subcutaneous or subcuticular sutures. If used alone, tissue adhesives are not recommended for lacerations longer than 4 cm or in areas of higher tension or frequent repetitive movements, such as joints or hands.

Other disadvantages of tissue adhesives include the inability to use antibacterial or other petroleum-based products on the wound; the recommendation not to swim, to limit forces that may prematurely remove the adhesive; and the greater risk of dehiscence. The tensile strength of tissue adhesives is significantly less than that of sutures. Despite these disadvantages, tissue adhesives represent a tremendous advance in the management of routine uncomplicated lacerations in non-tension areas. Patients routinely prefer tissue adhesives over traditional sutures.

Application of tissue adhesive begins with routine skin and wound preparation. The area must be dried and adequate hemostasis achieved before application of the adhesive. The wound margins are approximated as meticulously as possible, and care should be taken to prevent adhesive from getting between the wound margins. Applying tape (Steri-Strips) before application will facilitate wound margin approximation and make it easier to apply with similar results. Adhesive between the wound margins delays healing and increases the likelihood of wound dehiscence. The adhesive is applied to the entire length of the wound sufficient to cover 5 to 10 mm of skin adjacent to the margins. A single layer of adhesive is adequate if the current formulation is used. The adhesive sets in roughly 95 seconds.[12] Special care is taken to ensure that the adhesive does not run off and disturb adjacent tissues. Having the patient lie on the affected side will help prevent contamination of the eye near the wound and the opposing eye. Newer, high-viscosity formulations are now available that help limit this risk. Wounds may get wet but should not be immersed in water and should be blotted dry and not vigorously rubbed. An additional dressing may be desired by the patient but is not necessary.

Antibiotic Prophylaxis

Routine antibiotic prophylaxis for simple wounds has no scientific basis. A meta-analysis compared the rates of infection in patients with simple non-bite wounds receiving antibiotics with those in control groups. Of 1734 patients enrolled in the seven studies, patients treated with antibiotics had a slightly greater incidence of infection. The authors concluded that prophylactic antibiotics had no role in simple non-bite lacerations. Routine antibiotic use has obvious known complications, such as increasing resistance to antibiotics, gastrointestinal side effects (nausea, vomiting, *Clostridium difficile* colitis), and allergic reactions that are common and may result in significant morbidity and unnecessary cost.

Although irrigation and débridement are the most important means of preventing wound infections, antibiotic prophylaxis is recommended in some very limited circumstances. Prophylaxis must be tailored to each patient. Some recommendations are supported by scientific data, whereas others have few data to support their use and are based on established practice standards.

Contamination, Crush, and Host Factors

Antibiotic prophylaxis is often provided for patients with wounds with gross contamination, patients with severe crush injuries, and immunocompromised patients. Some authors recommend not closing these wounds and instead using delayed primary closure. If circumstances require wound closure despite the infection risk, many emergency clinicians recommend prophylaxis despite scarce data.[13]

Some authors believe that a patient with significant crush injury requires antibiotics. Crush injuries are high-risk wounds because they produce more devitalized tissue. A definitive answer may not be forthcoming, because it would be difficult to complete a well-controlled prospective, blinded study.

Patients with certain risk factors have increased wound infection rates. Large prospective studies of patients with surgical wounds showed an increased rate of wound infection in patients with diabetes, obesity, malnutrition, chronic renal failure, advanced age, and chronic steroid use. Because of higher rates of infection, some authors suggest the use of antibiotics in these patients, again based on individual circumstances. No controlled studies of antibiotic prophylaxis in these patients exist, however. Finally, some authors advocate prophylaxis for other host factors, such as prosthetic joints or risk for endocarditis. Little evidence exists to support either recommendation.

Open Fractures, Joint Wounds, and Gunshot Wounds

Wounds that involve joints or open fractures necessitate use of prophylactic antibiotics. Prospective randomized controlled studies have documented decreased infection rates in patients receiving antibiotics compared with placebo. Indeed, the time to antibiotic administration in these wounds was found to be the most important factor in decreasing wound infection rates.[14] Open fractures without evidence of significant soft tissue damage (avulsions and crushed or devitalized tissue) necessitate use of antibiotics for 24 hours. Open comminuted fractures or fractures with significant tissue damage necessitate 72 hours of antibiotics. For gunshot wounds, which are classified as a type of open fracture, the recommendations vary with the type of missile wound. Low-velocity missile wounds not treated with antibiotics showed no increased infection rate in a randomized controlled trial of 67 patients with fractures treated with a closed technique. High-velocity wounds with fracture, on the other hand, are associated with an increased risk of infection, and antibiotic therapy should be initiated early and maintained for 48 to 72 hours. In addition, patients with shotgun wounds with fracture should receive prophylaxis as well. Appropriate antibiotic therapy would be a cephalosporin with or without an aminoglycoside plus penicillin (to cover *Clostridia* species). Use of cefazolin (Ancef) 1 g every 8 hours and clindamycin 600 mg intravenously (IV) every 8 hours may be considered. For the severely contaminated wounds, tobramycin 1 mg/kg every 8 hours is added. Some recent data has proposed limiting aminoglycoside use altogether and only using cefazolin for Gustilo grade I/II open fractures and ceftriaxone for grade III open fractures. A single institution study showed little difference in infection rates after limiting aminoglycoside administration for open fractures.[13,14]

Bites and Puncture Wounds

Antibiotics are indicated for through-and-through intraoral lacerations, cat bites, some dog bites, some human bites, and some puncture injuries to the foot. Of all mammalian bites, school age children account for almost half of all patients in this category, and 70% of animal bites are from pets or animals known to the victim (also see Chapter 54).[15]

Cat Bites. Prophylaxis is required for patients with cat bites, especially bites to the hand. These bites tend to be deep puncture wounds that are difficult to irrigate adequately. These wounds also tend to become infected at a much higher rate than other types of bites. Cat bites have been reported to cause infections in 10% to 40% of all wounds. In one study, 13% of patients had signs of infection when they visited the ED, and 16% eventually developed infection. Other authors report that 80% of these bites become infected, although obvious selection bias limits this interpretation. Antibiotics seem to decrease the incidence of infection but a Cochrane review on mammalian bites suggested the limited literature on cat bites did prove antibiotic efficacy, except in hand bites. At this time, we still advocate for antibiotic prophylaxis in cat bites.

The organisms found in cat bites include *Staphylococcus* species, *Streptococcus* species, and, most often, *Pasteurella multocida*. *P. multocida* is usually found in infected cat bite wounds and is present in the normal oral flora of 70% of all cats. *P. multocida* is sensitive to penicillin, but the infection is often polymicrobial. *P. multocida* is resistant to dicloxacillin, cephalexin, and clindamycin, and there are many erythromycin-resistant strains. Amoxicillin with clavulanate (875 mg bid for 7 days) is the current recommendation for antibiotic prophylaxis for cat bites.

Dog Bites. Antibiotic prophylaxis for dog bites is more controversial. The infection rate has been reported as 6% to 16% for patients not receiving antibiotics. Dog bites tend to involve more crush injuries with tearing and avulsions rather than puncture wounds. As such, dog bites are usually more amenable to irrigation and débridement. Seven of eight randomized trials of dog bite wounds showed no benefit with antibiotics. However, pooled data for meta-analysis did show a small but statistically significant benefit from antibiotics. It may be logical to limit the use of antibiotics to high-risk wounds, such as hand injuries, deep puncture wounds, and wounds in older or immunocompromised patients.

Hand Bites. In addition to the previous bite wound recommendations, antibiotic prophylaxis of injuries to the metacarpophalangeal joints is advised. These wounds are assumed to be human bites until proved otherwise. Also known as "fight bites," these wounds have a high incidence of infection. Patients without signs of infection may be managed as outpatients. Close inspection after anesthesia has been applied is necessary to thoroughly evaluate the area for tendon involvement and/or penetration of the joint. If the joint is involved, irrigation is required. In some institutions, all these patients are taken to the operating room for a thorough washout. Patients with early signs of infection are admitted for intravenous antibiotics and débridement and irrigation. The choice of antibiotics reflects the predominant organisms of hand bite infections. *Streptococcus* and *Staphylococcus* species are common, but *Eikenella corrodens* and *Bacteroides* species are also typical pathogens. Because *Eikenella* is often resistant to clindamycin, first-generation cephalosporins, and erythromycin, patients with early infection are treated with amoxicillin with clavulanate. Patients with later infection are treated with intravenous extended-spectrum antibiotics (eg, ampicillin with sulbactam).

Intraoral Lacerations. Lacerations of the oral mucosa involve bacteria-rich oral secretions and may become infected slightly more often (6% to 12%) than other wounds. Rates of infection for through-and-through lacerations may be twice the rates for simple mucosal lacerations. Although few data suggest a clear indication for prophylactic antibiotics, one study showed that patients benefit from antibiotics if they are compliant with their regimen. Another study looked at all the literature (four studies) on antibiotics in intraoral lacerations and found the studies do not conclusively show a benefit to giving antibiotics in these types of wounds. It may be reasonable to limit antibiotic use to high-risk patients with through-and-through wounds. Penicillin 500 mg bid for 5 days is an appropriate choice of antibiotic.

Puncture Wounds of the Foot. Puncture wounds of the foot are seen frequently in the ED. These wounds are often caused by common carpentry nails, although other objects (eg, glass, metal, and wood) must be considered. Despite their simple appearance, these wounds may produce significant morbidity. The infection rate for puncture wounds has been reported to be 15%. Most wounds occur on the plantar surface, from the neck of the metatarsal to the toes. Simple cellulitis accounts for half of these infections. More significant infections include septic arthritis, abscesses, and osteomyelitis. *Pseudomonas* organisms cause 90% of osteomyelitis cases from puncture wounds. No data suggest a benefit from prophylactic antibiotics, but given the high risk of infection and serious complications, their use may be considered in select puncture wounds. *Pseudomonas* organisms should be suspected when the puncture went through a rubber-soled shoe is essential. Patients with puncture wounds to the foot require early follow-up. Ciprofloxacin is the drug of choice to treat outpatients with suspected wound infection when *Pseudomonas* is of concern. Cephalexin (Keflex) or dicloxacillin is adequate for staphylococcal and streptococcal coverage unless methicillin-resistant *Staphylococcus aureus* (MRSA) is likely. In cases suspicious for MRSA, sulfamethoxazole-trimethoprim or doxycycline is recommended.

Drains, Dressings, and Immobilization

Drains

Drains probably have no role in ED wound care. In general, drains are placed when a collection of fluid exists or may develop. The presence of a drain reduces the wound's resistance to infection, regardless of the materials used in its construction, and the use of drains should be avoided. In wounds likely to collect fluid (eg, around the elbow or knee), it is preferable to place the extremity at rest with a plaster splint or perform delayed primary closure.

Dressings

Various dressing materials are available. The microenvironment created by a dressing affects the biology of healing. The optimal wound climate must not interfere with the activity of fibroblasts and macrophages. The production of granulation tissue and migration of epithelial cells across the wound must be optimized.

Several factors should be considered in choosing the appropriate dressing. Dressings that prevent evaporation of water and keep tissues moist are helpful. A drying wound produces a thick, hardened scab that impedes the process of epithelialization. Excess fluid can lead to maceration of tissue and may be a potential culture medium for bacterial proliferation. Gaseous permeability is essential because epithelialization is accelerated greatly in the presence of oxygen. The wound-covering product should be impermeable to bacteria and other particulate matter that can contaminate the wound. It is important not to traumatize newly established tissue during dressing changes. The optimal dressing should have a nonadherent surface, be permeable to gases, and have a capacity to absorb some fluid but not allow desiccation. The outer barrier of the product should be impermeable to bacteria but permeable to water vapor. These products include films, hydrocolloids, foams, and hydrogels. The choice of dressing for ED wounds is primarily based on the amount of drainage that is expected.

Film dressings are thin membranes that are transparent, adhesive, and waterproof but are not absorptive. They are best reserved for wounds with low levels of drainage. Film dressings may be left in place for up to 7 days, as long as they do not leak or separate from the wound bed. For wounds with a moderate amount of drainage, moderately absorptive hydrocolloid dressings may be indicated. These dressings are thicker than films, semiocclusive, waterproof, and very comfortable for the patient. Like films, they can be left on for up to 7 days. Foam dressings are more absorptive and made of a soft cushion sponge-like material. Some may require a secondary dressing for adhesion and need to be removed every 3 days. Hydrogel dressings are moisture-donating water-based gels that are available in sheets attached to a semipermeable film. These dressings do not absorb fluids, so they must be used on relatively dry wounds. Patients often find these dressings to be the most comfortable, but they need to be changed every 1 to 3 days. The least expensive and simplest method of dressing a straightforward, uncomplicated laceration is to use Vaseline-impregnated gauze or gauze on top of a thick layer of antibiotic ointment. These should be changed daily to prevent desiccation.

Immobilization

Wounds in proximity to joints must be immobilized as part of routine care. Splinting the injured body part places the injury at rest and hastens healing. Failure to splint appropriately exposes the healing tissue to the dynamic forces of muscular contractions, ultimately slowing the healing process and increasing scar size. In addition, immobilization decreases lymphatic flow and minimizes spread of microflora from the wound.

DISPOSITION

Wound Care Instructions

It is difficult for patients to identify and recognize the signs of infection (Box 52.2). Discharge instructions must be clear, understandable, and reasonably comprehensive. Instructions should include daily care, observation for signs of infection, suture

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BOX 52.2

Wound Care Instructions

I. Elevate the injured extremity above the level of the heart. Wear a sling when appropriate.
II. Cleanse daily in a gentle manner to remove debris and crusting that develops. Use dilute hydrogen peroxide.
III. Immobilization should be maintained at least until suture removal.
IV. Signs of infection
   A. Redness
   B. Increasing pain
   C. Swelling
   D. Fever
   E. Red streaks progressing up an extremity
V. Wound check
   A. As needed to check signs of infection
   B. Routine at 48 hours for high-risk wounds
VI. Suture removal (*Note:* Suture may be removed earlier if Steri-Strips reinforce the wound.)
   A. Face: 3 to 5 days (always replace with Steri-Strips)
   B. Scalp: 7 to 10 days
   C. Trunk: 7 to 10 days
   D. Arms and legs: 10 to 14 days
   E. Joints: 14 days

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removal dates, and a follow-up source. It should be recommended to the patient that injured extremities be elevated during the first 24 to 48 post-traumatic hours and explained that elevation lessens edema, hastens healing, and mollifies pain. The wound should be protected as described previously or cleaned daily to remove crust formations. It is safe for patients to bathe and get the wound wet 24 hours after injury. Daily swabbing with half-strength hydrogen peroxide rids the wound of debris and any blood clot that forms between the sutured edges. Hydrogen peroxide should not be used after separation of the scab, because it is toxic to the epithelium and may produce bullae.

Wound infection is difficult for the untrained observer to distinguish from the inflammatory response of injury and subsequent healing. Patient education in this regard should be cautious and straightforward (eg, return or seek follow-up for redness, swelling, increased pain, fever, pus, or red lines progressing up an extremity). An injury classified as high risk must be reexamined 48 hours after the trauma, regardless of its appearance. Discharge instructions should include highlighting the possibility that a foreign body may be present despite efforts to remove it. Return precautions outlining signs of wound infection are essential.

Suture removal times vary, but generally they are approximately 4 days for the face and 7 to 14 days for other body parts (see Box 52.2). Considerations include cosmetics, dynamic forces in proximity to the injury, static skin tension, blood supply, and anticipated healing rates.

Tetanus Immunization

The incidence of tetanus in the United States is rare with only 233 cases reported during the 2001 to 2008 surveillance period with a case fatality rate of 13.2%.[16] Most tetanus patients in the United States are older than 50 years old. Immunization status needs to be considered in all patients with wounds, regardless of severity. Forty percent of all cases of tetanus occur in individuals who have either minor wounds or no recollection of injury. These numbers raise serious questions regarding the validity of separating immunization recommendations according to clean and tetanus-prone wounds. Studies show that many people are inadequately immunized, especially patients older than 70 years, immigrants, and people with no education beyond grade school.[4,17] Also, patient immunization histories are often unreliable. Given the inability to predict which wounds are at high risk, all wounds are approached with suspicion.

The usual incubation period for tetanus is 7 to 21 days (range, 3 to 56 days). Immunization is given as soon as possible but can be given days or weeks after the injury. The dose of tetanus toxoid (T) or diphtheria, pertussis, and tetanus toxoids (DTaP) is 0.5 mL intramuscularly, regardless of the patient's age. Inadequately immunized patients need a dose of DTaP and tetanus immune globulin (TIG). The TIG dose is 250 IU for all ages 7 years old or older and 4 IU/kg IM up to 250 IU for ages younger than 7 years old (Table 52.1). A single injection of TIG provides protective levels of passive antibodies for at least 4 weeks. The immune globulin and toxoid may be given during the same visit but should be administered with a different syringe at separate sites. The literature suggests that emergency clinicians need to be more diligent administering TIG, because it is often not provided when indicated.

Because studies suggest that 10% to 40% of the population in the United States is inadequately immunized against pertussis, pertussis vaccination is recommended along with tetanus toxoid.[17] Immunity to pertussis wanes approximately 5 to 10 years after vaccination. Since the 1980s, the number of reported pertussis cases has steadily increased, especially among adolescents and adults. Children younger than 11 years old should receive the DTaP immunization. In 2005, a tetanus toxoid, reduced

TABLE 52.1

Tetanus Prophylaxis for All Patients With All Wounds[a,b]

IMMUNIZATION HISTORY	DTAP (0.5 mL)	TIG (250 IU)
Fully immunized, <10 years since booster	No	No
Fully immunized, >10 years since booster	Yes	No
Incomplete series (<3 injections)	Yes[c]	Yes

[a]All injections are intramuscular.
[b]Consider more frequent immunization for elderly patients. Tdap recommended for ages 11 to 64 years old (Adacel, Sanofi Pasteur) and 65 years old and older (Boostrix, GalaxoSmithKlineBiologicals), although both products likely effective in the older than 65 age group.
[c]Refer these patients to complete their series; DTaP in 6 weeks and 12 months.
DTaP, Diphtheria, pertussis, tetanus toxoids; *TIG,* tetanus immune globulin.

diphtheria toxoid, and acellular pertussis vaccine, adsorbed (Tdap) product formulated for use in adults and adolescents was licensed in the United States for people 11 to 64 years old. Updated recommendations allow for Tdap (Boostrix, GlaxoSmithKline Biologicals) to given to patients 65 years old and older, although it is likely that either Adacel or Boostrix vaccine will provide protection.[17] When possible, it is recommended that this triple combined formulation be used in the ED for tetanus prophylaxis of adolescents and adults. Although all four injections (T, diphtheria and tetanus toxoids [DT], TIG, and DTaP) are considered safe and effective in pregnancy, because of limited experience during pregnancy the recommendation is to use DT. However, DTaP is recommended immediately postpartum, including for breast-feeding women.

Box 52.3 summarizes the principles of wound care management.

BOX 52.3

Summary of Wound Care

I. Stabilize patient
II. History (include tetanus immunization and allergies)
III. Physical examination
    A. Neurovascular examination
    B. Anesthesia: Bupivacaine 0.5% without epinephrine, regional or local
    C. Bloodless field: Tourniquet or sphygmomanometer for extremities
    D. Thorough examination of anatomic structures, skin, nerves, tendons, blood vessels, bones, muscles, fascia, other (ducts, cartilage)
    E. Consultation if indicated
IV. X-ray films to detect injury to bone or the presence of foreign bodies (plain films, CT or ultrasound)
V. Wound preparation
    A. Cut—do not shave—surrounding hair
    B. Prepare surrounding skin with a chlorhexidine-alcohol solution
    C. Sharp débridement of foreign matter and devitalized tissue
    D. High-pressure irrigation with saline or a 1% povidone-iodine (Betadine) solution
VI. Wound closure
    A. Tape, staples, or suture
    B. Do not use subcutaneous sutures unless the wound is under high tension
VII. Antibiotics
    A. Apply topical antibiotics
    B. No systemic antibiotics unless wound is very high risk
VIII. Dress and immobilize: Consider a transparent gas-permeable dressing
    A. Wound care instructions (see Box 52.2)
        1. Signs of infection
        2. Elevation
        3. Wound check if necessary
        4. Suture removal as soon as possible

KEY CONCEPTS

- Risk factors for wound infection include crush mechanism; long (>5 cm) deep penetrating wounds; high-velocity missiles; diabetes; and contamination with saliva, feces, soil, or other foreign matter.
- The most effective intervention to decrease infection is thorough cleansing, with use of saline or tap water irrigation at approximately 8 psi. Attaching an 18-gauge needle to a 35-mL syringe creates an irrigant force of 7 or 8 psi, which decreases bacterial counts.
- Soaking wounds in povidone-iodine (Betadine) is more toxic than beneficial to healthy tissue. Prepare the skin with a chlorhexidine-alcohol solution.

- Antibiotics are indicated for through-and-through intraoral lacerations, cat bites, some dog bites, some human bites, puncture injuries to the foot in high-risk individuals, open fractures, and wounds involving exposed tendons or joints.
- High-risk wounds should not be sutured primarily but may be repaired in 4 or 5 days (ie, delayed primary closure).
- Tetanus immunization should be provided soon after injury but can be given days or weeks later. The usual incubation period for tetanus is 7 to 21 days (range, 3 to 56 days).
- Tdap is recommended for patients 65 years old or older requiring tetanus prophylaxis.

The references for this chapter can be found online by accessing the accompanying Expert Consult website.

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CHAPTER 52: QUESTIONS & ANSWERS

52.1. Which of the following is associated with an increased risk of infection?
  A. Avoidance of epinephrine use in wound anesthesia
  B. High-pressure irrigation
  C. Use of clippers instead of razors for hair management near wound
  D. Use of silk suture material
  E. Use of tape over sutures for wound closure

Answer: D. Silk yields the highest infection rates, whereas monofilament synthetic substances have the lowest risk of infection.

Risk Factors for Wound Infection

1. Injury more than 8-12 hours old (varies depending on the following factors)
2. Location: leg and thigh, then arms, then feet, then chest, then back, then face, then scalp
3. Contamination with devitalized tissue, foreign matter, saliva, or stool
4. Blunt (crush) mechanism
5. Presence of subcutaneous sutures
6. Type of repair: risk greatest with sutures > staples > tape
7. Anesthesia with epinephrine
8. High-velocity missile injuries

52.2. A 32-year-old man presents with 20 stab wounds to his arms and legs after sustaining an assault. He weighs 80 kg. Which of the following is an appropriate dosage of wound anesthesia?
  A. 240 mg of 1% lidocaine
  B. 320 mg of 0.5% bupivacaine
  C. 400 mg of 0.5% bupivacaine with epinephrine
  D. 700 mg of 1% lidocaine with epinephrine

Answer: A. In adults, the maximal reported safe dose of bupivacaine is approximately 2.5 mg/kg without epinephrine and 3.5 mg/kg with epinephrine, assuming the injection is a wound infiltration technique and not one in a highly vascular area. General dose guidelines for lidocaine are 3 and 5 mg/kg without and 5 to 7 mg/kg with epinephrine, respectively. A 1% lidocaine solution contains 10 mg/mL. The actual percent solution does not matter; the total milligram dose does.

52.3. A 23-year-old female presents with a laceration to her thigh. As you begin to apply anesthetic, she tells you that when she went to the dentist she had an allergic reaction to procaine. Which of the following should you use?
  A. Benzocaine
  B. Benzocaine with epinephrine
  C. Bupivacaine
  D. Lidocaine from a multidose vial
  E. Tetracaine

Answer: C. Allergy to local anesthetics is uncommon. Two distinct groups of "caine" anesthetics exist. The esters include procaine, tetracaine, and benzocaine. The second group, including lidocaine and bupivacaine, belongs to the amide family. Allergy to the esters is uncommon. True allergy to agents in the amide family is rare. No cross-reactivity occurs between the amide and ester families, so an agent from a different group may be chosen. A "preservative-free" preparation should ideally be used because the para-aminobenzoic acid in multidose vials may cause an amine-like reaction that may be confused with an allergy to the primary agent.

52.4. Which of the following is most likely to require no antibiotic prophylaxis?
  A. Cat bite
  B. Diabetic with contaminated wound
  C. Dog bite
  D. Human bite
  E. Puncture wound through rubber sole

Answer: C. Antibiotic prophylaxis is often provided for patients with wounds with gross contamination, patients with severe crush injuries, and immunocompromised patients. Prophylaxis is also required for patients with cat bites. Seven of eight randomized trials of dog bite wounds showed no benefit with antibiotics. Human bites or lacerations to the metacarpophalangeal (MCP) joint are termed "fight bites," and these wounds have a high incidence of infection. Thus, of the choices given, dog bites have the lowest incidence of infection and therefore are the least likely to require prophylactic antibiotics.

52.5. Antibiotic coverage of a cat bite must target which of the following pathogens?
   A. *Bacteroides* species
   B. *Clostridium perfringens*
   C. *Eikenella corrodens*
   D. *Pasteurella multocida*
   E. *Pseudomonas* species

Answer: D. The organisms found in cat bites include *Staphylococcus* species, *Streptococcus* species, and, most often, *P. multocida. P. multocida* is usually found in infected cat bite wounds and is present in the normal oral flora of 70% of all cats. *P. multocida* is sensitive to penicillin, but the infection is often polymicrobial. *P. multocida* is resistant to dicloxacillin, cephalexin, and clindamycin, and there are many erythromycin-resistant strains. Amoxicillin with clavulanate is the current recommendation for antibiotic prophylaxis for cat bites.

52.6. A 74-year-old patient presents with a gaping wound from a dog bite, complaining of pain at the site. The dog belongs to a friend, has reportedly had "all his shots," and is in custody. The patient is from Central America but has lived in the United States for more than 50 years; he does not recall his immunization history. Besides copious irrigation and wound dressing, which of the following should be included in the treatment of this patient?
   A. Diphtheria, pertussis, tetanus toxoids (DTaP) and tetanus immunoglobulin (TIG)
   B. Rabies immunization
   C. Tetanus toxoid
   D. Tetanus toxoid and immunoglobulin
   E. B and D

Answer: A. Studies show that many people are inadequately immunized, especially patients older than 70 years old, immigrants, and people with no education beyond grade school. Patient immunization histories are often unreliable. Given the inability to predict which wounds are high risk, all wounds should be approached with suspicion. Inadequately immunized patients need a dose of DTaP and TIG. Because studies suggest that 10% to 40% of the population in the United States is inadequately immunized against diphtheria, diphtheria vaccination should be given along with tetanus toxoid. Many adults are not immunized against pertussis, and the incidence of disease has been rising since the 1980s. In 2005, a new acellular form of the pertussis vaccine became available and is recommended for all adults.