CHAPTER 111

LACERATION REPAIR

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INTRODUCTION

Over one-third of injuries in children involve a laceration, making it the most common specific injury for which care is sought in a pediatric emergency department (1, 2). In addition, a significant number of these patients seek treatment in primary care clinics (3). Laceration repair accounts for one-half of all procedures performed on injured children (1, 2).

A laceration refers to a traumatic linear disruption of the dermis. Repair of such injuries serves several purposes. Early repair following appropriate wound management (Chapter 110) restores the skin's protective barrier and thereby reduces the risk of infection and fosters rapid healing. Suture placement also can assist in hemostasis by tamponading vessels involved in the laceration. Providing optimal cosmesis, particularly for wounds involving the face, is another important goal with laceration repair.

The incidence of lacerations in children is strongly correlated with the developmental level of the child. The initial rise in incidence occurs with the ability to ambulate. Lacerations peak at 2 years of age when the child has attained greatest mobility but lacks equivalent motor coordination. Half of childhood lacerations occur in children under 5 years of age, and frequently involve falls on broken glass bottles, wooden furniture, asphalt, or concrete (1). Lacerations resulting from assaults or altercations are more common in adolescents.

Animal bites also are a frequent source of lacerations in children. This is especially true in the preschool and early school years, when inadvertent provocation can result in an attack by the animal.

Common sites of lacerations in children are the head (60%), the upper extremities (23%), and the lower extremities (15%) (1, 4). Lacerations of the head or face are proportionately greater in children under 2 years of age, as older children are more likely to break a fall by extending an arm or leg.

The majority of childhood lacerations can be treated without subspecialty assistance (1, 2). Need for consultation depends on a number of factors, including the level of skill and experience of the clinician, the complexity of the laceration and involvement of underlying structures, the location of the laceration, and the ability of the child to cooperate.

In view of the frequency of lacerations during childhood, the importance of early repair, and the straightforward methods required for the majority of these injuries, every clinician treating acute injuries in children should be capable of suturing lacerations.

ANATOMY AND PHYSIOLOGY

Knowledge of the anatomy and regenerative properties of the skin is crucial to performing an optimal laceration repair. Layers of the skin are depicted in Figure 111.1. The epidermis is the most external layer and is composed of epithelial cells whose function is to protect deeper tissues from infection and desiccation.

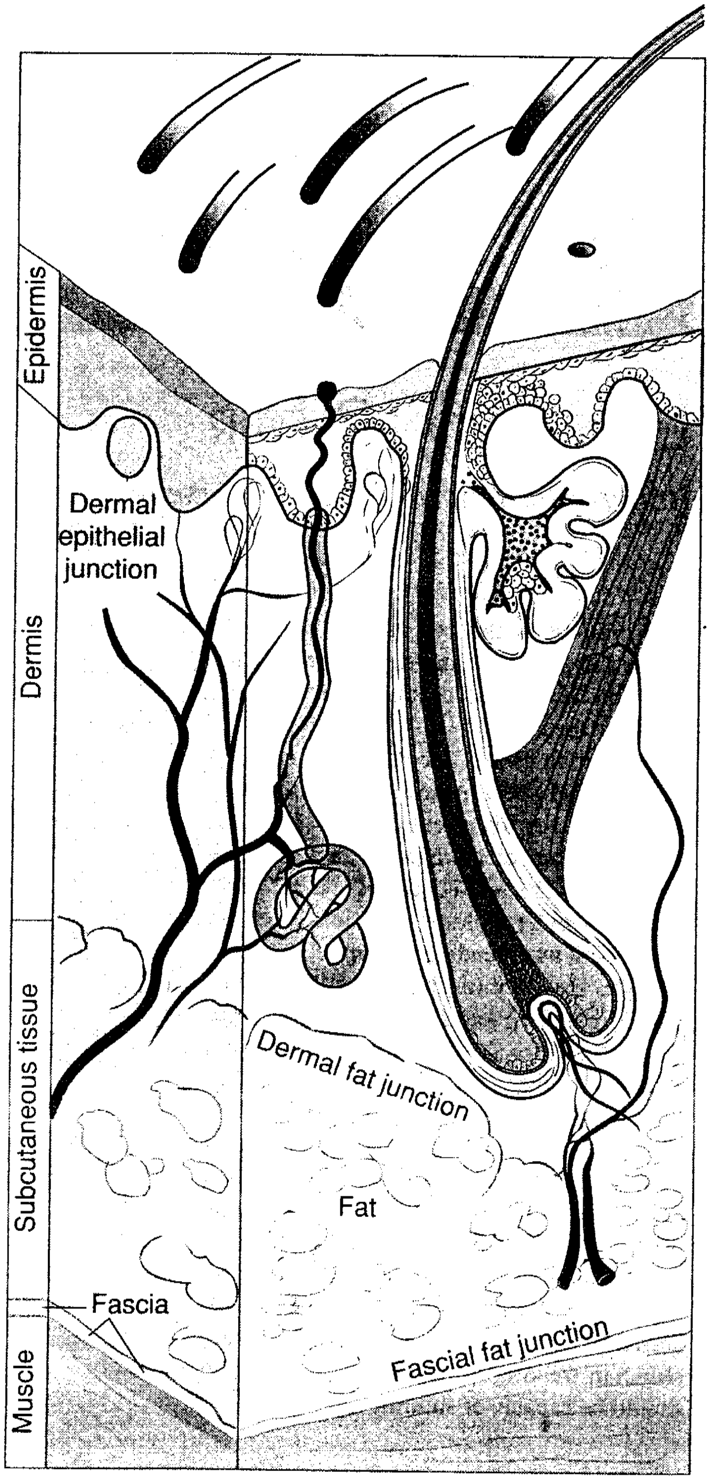


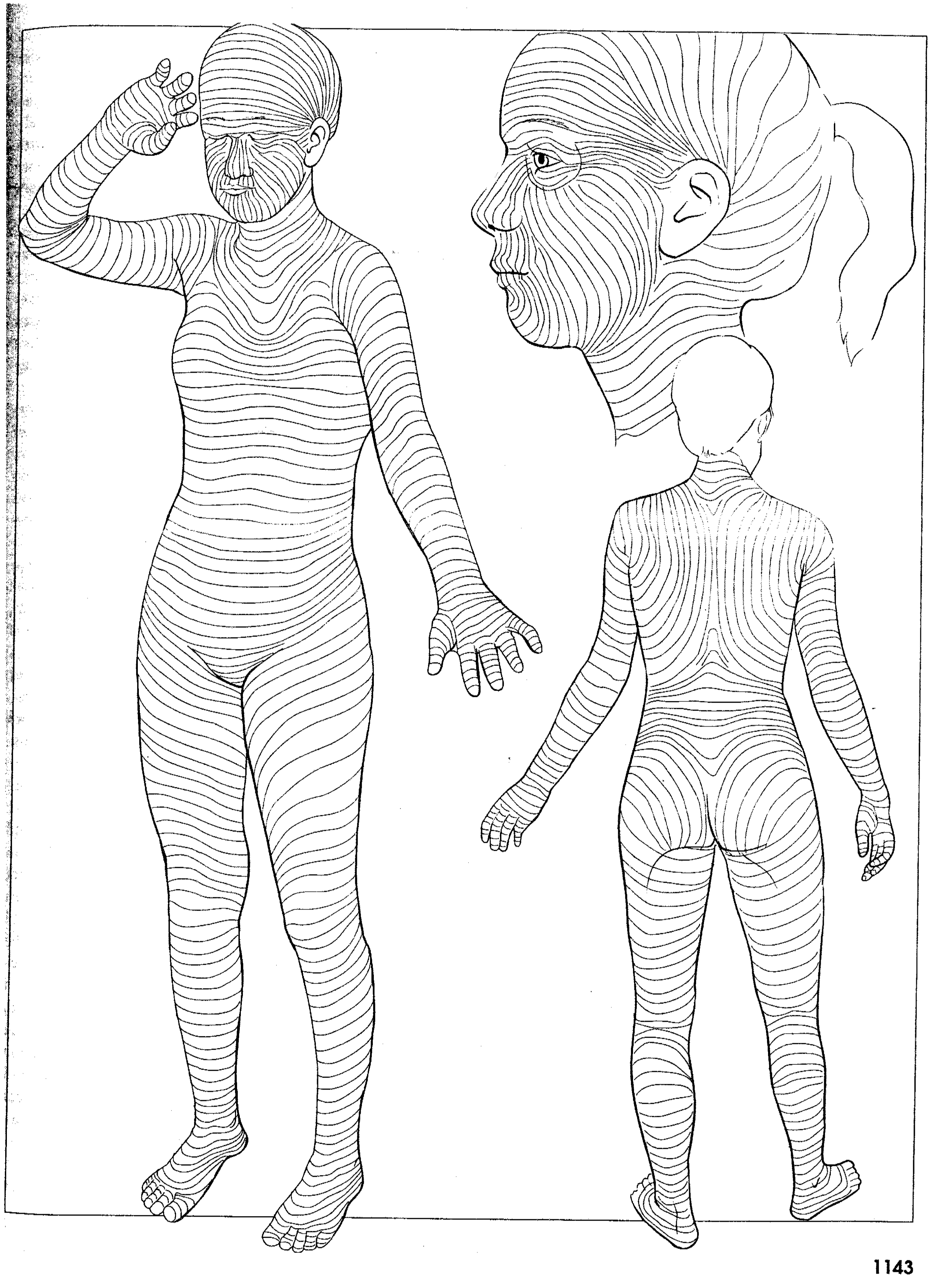
Figure 111.1
Anatomy of the skin layers.

Immediately subjacent is the dermis which contains blood vessels, nerve endings, collagen, and fibroblasts. Below the dermis is subcutaneous tissue which is mainly composed of fat cells. Hair follicles, nerve fibers, and blood vessels also are located in this layer. The extent of subcutaneous tissue varies with the particular area of the body. The subcutaneous tissue is bounded below by a sheet of connective tissue called the fascia.

The depth of the wound and the particular layers that have been disrupted are important factors in determining the best type of closure. Early contraction at the deeper levels following injury frequently results in an inaccurate estimate of wound depth. The wound must be explored thoroughly for this reason. The clinician must also carefully search for injuries to underlying structures, such as tendons which may have shifted with flexion or extension from below the visible external area of involvement. Certain layers retain sutures best: the fascial-fat junction, the dermal-fat junction, and the level just below the dermal-epithelial junction (Fig. 111.1). Adequate support of tissues is a prerequisite for an optimal closure and requires approximation of each involved layer. Improper alignment of layers results in an uneven surface which produces a shadow and obvious scarring.

Intact skin is under constant tension. This tension has both a static and a dynamic component. The skin in a particular location of the body possesses an intrinsic amount of tension which runs in a distribution depicted by Kraissel's lines, also known as the relaxed skin tension lines (RSTL) (11, 14) (Fig. 111.2). Tension along these lines determines the initial extent of separation that occurs along a laceration and the ultimate width of the scar. Sutures provide temporary support until the skin can regenerate tissue capable of overcoming this tension and maintaining closure of the wound. The extrinsic component of tension is produced by underlying muscles and joints. Skin overlying the knee, for example, is under varying amounts of tension depending on whether the knee is flexed or extended. Lacerations running perpendicular to these lines of tension subsequently gape more and require stronger sutures over a longer period to provide adequate support. These lacerations are consequently at an increased risk of scarring. Lacerations that run parallel to joints, normal skin folds, or Kraissel's lines can be expected to heal more rapidly and with better cosmetic results.

Figure 111.2.
Kraissel's lines or relaxed skin tension lines.



The normal healing process of skin occurs over a prolonged period and involves multiple, sometimes overlapping, stages. The process is typically divided into coagulation, inflammation, epithelialization, angiogenesis, collagen metabolism, and wound contraction. Coagulation occurs within the first hours following injury and involves vasospasm, platelet aggregation, and fibrous clot formation. The inflammatory phase is marked by increased capillary permeability and invasion of the wound by leukocytes. Neutrophils and macrophases release proteolytic enzymes which break down damaged tissue. Both cells possess phagocytic properties and ingest debris and bacteria. Chemotactic factors which stimulate fibroblast migration and replication are released during this phase. The inflammatory process peaks about 24 hours after the injury and lasts for several days.

The epidermis is the only layer with true regenerative capabilities. All other layers heal by laying down collagen or scar tissue. New epithelial cell growth occurs along the lacerated edges of the epidermis. In a sutured laceration complete bridging of the wound occurs within 48 hours. Epithelial cell growth is stimulated by the same factors that affect fibroblast proliferation (10). The placement of sutures creates a new wound through the epithelium and the new epithelial cells will migrate along the track of the suture. These cells frequently disappear once the suture is removed; however, when sutures are left in place for prolonged periods of time or are placed under excessive tension, these epithelial cells are more likely to remain and form punctate scars along the edge of the wound.

The various stages of wound healing depend on the delivery of substrates including nutrients, oxygen, and inflammatory cells to the site of injury. New vessel growth or angiogenesis is crucial in providing this means of delivery. Capillary production in the area of injury is stimulated by hypoxia, lactase production and stimulating factors produced by macrophages (10). Angiogenesis peaks 4 days following injury.

The formation of collagen, the principal structural protein, is essential in restoring the original tensile strength of the skin. Fibroblast deposition of collagen components begins within 48 hours of the injury. Various enzymatic processes result in the formation of fibrils. Subsequent cross-linking of these fibrils gives the collagen its maximal strength. Although the process of collagen synthesis reaches a peak in the first week, production and remodeling proceeds for up to 12 months. A new scar will reach only one-quarter of its ultimate strength by a month and less than two-thirds by 4 months (5).

Wound contraction is a poorly understood process in which the full wound thickness moves toward the center of the wound. This occurs 3 to 4 days following the injury and appears to be independent of collagen formation. Current research suggests that contractile cells called myofibroblasts may be involved in this process (10).

Various factors, both internal and external, will inhibit the normal process of healing. Underlying immune deficiencies or prolonged steroid use can affect the inflammatory stage. The presence of crushed tissue or debris surrounding the laceration, as frequently occurs with blunt trauma, will significantly impede epithelial cell replication. Epithelialization is optimized by meticulous attention to wound cleansing, debridement, and foreign body removal (Chapters 110 and 113). Collagen synthesis is a complex process that depends on the presence of a number of trace minerals, vitamins, and plasma proteins, as well as an adequate supply of oxygen. Poor nutrition, underlying illness, or vascular disease will adversely affect this process.

As the microscopic process of healing proceeds, the appearance of the wound also undergoes predictable stages of evolution and remodeling. The clinician must be cognizant of this transformation and prepare the patient who otherwise might be anxious to have an unsightly scar revised before it has reached its final state. What may initially appear to be a cosmetically appealing result following suture removal often will go through a stage in which it becomes increasingly thickened, reddened, and elevated. This occurs during the active period of fibrous tissue production and remolding which lasts approximately 3 months. Over the ensuing 3 months the scar can be expected to fade and recede as capillaries collapse and the cellular content is replaced by connective tissue, so that the appearance 6 months following the initial laceration is essentially the final scar.

Hypertrophic scarring and keloid formation are the result of abnormal healing that can occur despite proper wound management and suturing technique. Hypertrophic scars are composed of red, raised, pruritic tissue which is the result of excessive collagen deposition occurring within the original boundaries of the wound. Formation of such scars is related to the amount of time the wound spends in the inflammatory phase and the presence of excessive tension on the wound. Keloids are nodular masses of scar tissue which also contain increased amounts of immature collagen and migrate beyond the original extent of the wound. Keloids occur with greater incidence in dark-skinned individuals and have a higher propensity for certain areas of the body such as the sternum, deltoid, and mandible.

Children appear to have advantages in healing ability over adults. Studies suggest that in adults stages of healing begin later, occur at a slower rate, and do not reach the same level as in children. With increasing age collagen biosynthesis and cross-linking are decreased (5), the rate of epithelialization is reduced (6), and the proliferative capacity and contractility of fibroblasts are diminished (7). The underlying reason for these changes is difficult to determine due to the presence of multiple confounding factors. It is unclear whether these changes in wound healing are the result of prolonged environmental exposure, underlying disease, or simply the natural process of aging.

INDICATIONS

Basic goals of wound repair are to restore the integrity and the function of the injured tissues (11). To achieve these goals, preventing infection is important and minimizing scar formation is desirable. Wound closure ensures early restoration of the natural skin barrier, avoiding prolonged healing and protecting against subsequent infection. Wounds located on the face are of obvious concern regarding scar formation; however, excessive scar formation in any area can be a source of annoyance or embarrassment for the patient.

Minor soft tissue wounds are a common, unavoidable part of pediatric acute care. Anxiety of the patient and family surrounding the repair of these injuries, especially facial wounds, can be a source of much stress for the clinician. For these reasons, the ability to approach this situation in a clearly planned and confident manner is essential to the clinician's long-term survival in pediatric emergency care. Skilled minor wound care can be a source of great patient and personal satisfaction and should receive major consideration in the education of emergency care providers.

Reasons to Seek Consultation

Not every wound should be repaired by the emergency physician. Consultation should be considered in the following circumstances (11, 12):

1. Wounds with an underlying fracture;
2. Wounds requiring nerve repair, vascular repair, or tendon closure;
3. Wounds that would be better treated under general anesthesia due to their extent or location;
4. Situations in which the emergency physician has insufficient time to devote to proper care of the wound; and
5. Circumstances the emergency physician considers beyond his or her expertise.

The consulting service will vary with the injury and can range from general surgery (for a laceration complicated only by its extent) to plastic surgery, otorhinolaryngology, oral surgery, and orthopedics for more specialized circumstances.

A difficult situation arises when the family insists on a plastic surgeon for a relatively minor wound that is well within the capacity of the emergency physician. To readily consult plastic surgery in all such cases is a poor strategy (13). Often a simple closure yields a wholly acceptable result and the expense of a plastic surgeon and the time delay caused by such consultation is inappropriate for the situation (13). The clinician should reason with and inform the family that he or she is capable of handling the wound. The clinician also should inform the family that the need for revision will be unlikely but, if required, this can be performed without difficulty at a later date under more favorable conditions.

With complicated wounds, immediate repair even by an experienced plastic surgeon may not always be the best strategy (14). A complicated revision in the acute phase is considered less desirable by some authorities for the following reasons: (*a*) a higher risk of infection may necessitate suture removal and undermine the initial effort; (*b*) it is more difficult to make the proper cuts for Z-plasty, etc. in damaged tissue as opposed to the firm scar base that will be present at a later date; (*c*) less time is available to study the natural tendencies of the wound; and (*d*) the patient has no basis of comparison with which to judge the outcome of plastic surgery (14).

Some emergency physicians will feel comfortable with extensor tendon repair; however, the requirement for prolonged close follow-up and attention to patient compliance coupled with the potential for significant disability make referral a strong consideration in these cases. The emergency physician also must be aware that delayed repair of certain injuries, including nerve and tendon transection and complicated facial lacerations, is an acceptable response on the part of his or her consultant (13).

Infectious Considerations

The main reason not to close a soft tissue wound is to avoid a subsequent infection. The risk of infection in a wound depends on the interaction of patient factors, the wound environment, and the care provided by the physician (9, 11, 15–18). When wound evaluation indicates that primary repair would be associated with a high risk of infection, it is recommended to leave the wound open for delayed primary closure or to allow healing by secondary intention (11, 17).

Delayed primary closure is rarely used in the management of pediatric wounds, because the rate of wound infection in children is quite low. Studies examining all types of pediatric lacerations primarily repaired with sutures report infection rates of under 2% (19, 20). It also is important to realize that if primary repair fails due to wound infection, the subsequent management is similar to delayed primary closure (15).

Patient Factors

Patient factors associated with an increased rate of infection include the presence of diabetes, immunosuppression, renal failure, liver failure, obesity, and malnutrition (9, 1–18). Infection rates 5 to 8 times higher in surgical wounds have been demonstrated in the presence of diabetes, obesity, and malnutrition (18). Wound infection rates for pediatric patients with these conditions are unknown as wound studies generally exclude such patients (19, 20). Presence of an underlying illness should not be the sole reason for avoiding wound closure, and the majority of wounds in these patients are amenable to primary repair. It is important, however, to pay close attention to wounds in such patients and to ensure adequate follow-up.

Local Factors

Local factors regarding the wound itself are the main source of wound problems in the ED (9). The clinician should always consider the following factors before wound closure.

Time Delay

Time is a variable factor in the closure of wounds as some, such as a highly contaminated puncture wound, should never be closed and others may be safely closed at almost any time after the injury (15). The golden period of wound repair is frequently mentioned but is a concept that varies depending on the evaluation of the individual wound. Primary determinants of an acceptable time period for primary wound closure are the degree of contamination of the tissue and the vascular supply of the area (9, 15).

Several studies have demonstrated that if a wound contains greater than 10^5 bacteria per gram of tissue the infection rate will be high (21–23). The mean time to achieve this level of contamination in one study was 5.1 hours, leading some authorities to consider the golden period to be quite short (21). Actual clinical studies, however, have produced results that support individual evaluation of wounds to determine if the time delay for closure is acceptable. No difference was found in infection rates for pediatric wounds sutured greater than 6 hours after injury as compared with those repaired earlier (20). A study of wounds in a third world setting found that it was safe to close general wounds for a period up to 19 hours whereas scalp wounds could be closed at any time

(24). Regarding hand wounds, time was not a factor in infection for a period up to 18 hours (23).

The primary determinant of the patient's ability to resist wound infection will be the local circulation to the wound site (25). For that reason injuries to well-vascularized areas such as the scalp, face, and tongue may be comfortably repaired many hours after presentation (9, 25). In the previously mentioned study, 97% of scalp wounds closed after 19 hours healed without complications (24).

Wound Contamination and Crush Injury

The degree of bacterial contamination is an important determinant of wound infection (21-23). Unfortunately, the method to perform quantitative bacterial analysis of a wound is somewhat cumbersome and time consuming, keeping this practice largely an item of research interest. The presence of devitalized tissue in a wound is considered a major risk factor for wound infection (11, 25, 27). Experimentally, inserting devitalized fat, muscle, or skin into a wound increases the infection rate (27). This occurs through inhibition of leukocyte function, creation of an anaerobic environment, and the support of bacterial growth by the "culture medium" nature of the devitalized tissue (27).

Crush injuries are generally considered at higher risk for infection due to the presence of devitalized tissue and, more importantly, disturbances of local blood flow (26). Although this makes intuitive sense, clinical series supporting this fact are limited. Separate studies on hand injuries demonstrated conflicting results when comparing infection rates in crush versus laceration type injuries (22, 28). In areas where the vascular supply is good such as the scalp, the overall infection rate will be low regardless of the mechanism of injury (24, 29).

The ability to sharply debride devitalized or heavily contaminated tissue will have a major impact on the decision to close a wound primarily (9, 17). Debridement can convert a crushed, dirty wound into a clean, sharply incised laceration suitable for primary repair. Similarly, adequate wound irrigation can be expected to reduce the bacterial contamination of a wound and decrease the rate of subsequent infection (Chapter 110).

Wound Location

Although wound location itself will usually not preclude primary repair, some general issues are pertinent to remember in evaluating wounds. Most studies demonstrate an increased rate of wound infection for injuries to the lower extremities (19, 20, 29). This is thought to be due to the relatively poor blood supply to the lower extremities (19, 25). The foot may be at a particularly high risk (11). Upper extremity wounds also are considered at higher risk for infection, particularly hand wounds, for reasons similar to the lower extremities (25, 29).

Areas with significant exposure to endogenous bacteria such as the mouth, vagina, and perianal area are theoretically at high risk for infection (11). These same areas, however, also have an excellent vascular supply, counterbalancing the increased bacterial exposure (25). Closure of wounds in the mouth is generally considered acceptable if no major time delay has occurred (30, 31). The low rate of infection of episiotomy incisions indicates some margin of safety for primary wound repair in the perineum. If in doubt about closure in special areas consultation should be considered.

Location of a wound also may influence where the repair is best undertaken. Wounds of the perineum may require closure in the operating room for the best result in terms of patient fear and anxiety. Wounds in inaccessible areas of the oral cavity also may require such management.

Bite Wounds

Considerable controversy exists surrounding the proper management of both human and animal bite wounds. The clinician's decision for closure in the case of a bite wound must weigh the various factors related to wound infection with the supposition that the wound is contaminated with bacteria before therapeutic intervention (9). The important considerations then become the vascular supply to the area and the ability of the clinician to clean the wound and decrease the bacterial contamination present (32).

In all types of bite wounds the hand is at especially high risk for infection (32-39) due to the relatively poor blood supply of many structures in the hand, as well as anatomical features which make cleaning a bite of the hand difficult if not impossible (33).

Human Bites

The notorious reputation of human bites is primarily based on one injury alone, the closed fist injury, when a laceration over the flexed metacarpal-phalangeal joint is sustained from the tooth of an opponent (32). Forces involved to create a skin break are generally sufficient to inoculate the tendon and its coverings which lie just under the skin in this area. Frequently, deeper injury occurs to the bone, cartilage, and joint space. When the hand is subsequently extended, the bacteria is carried into areas not accessible to routine cleansing in the ED (32, 33). In the pediatric age group these wounds are usually infected by the time of presentation (36, 37). Admission to the hospital is generally indicated for an infected closed fist injury (33, 37)

All patients presenting with a wound over the metacarpal head should be considered to have a human bite wound until proven otherwise. It is prudent to treat all such wounds in this location as a bite wound regardless of the history provided by the patient. If the wound is not infected at presentation it should be thoroughly evaluated by wound exploration and radiographic study to detect any underlying injury that would prompt hospitalization. Patients scheduled for outpatient treatment must have their wounds thoroughly cleansed, left open, and elevated. They are routinely treated with antibiotics and must be capable of early follow-up (33).

Human bites in other areas are of no greater risk than animal bites (32). Two studies of human bites in children indicate that the chance of infection in superficial abrasions is extremely low and that antibiotics are of no value. The literature on suturing human bite lacerations in children is limited; however, the placement of deep sutures was associated with an increased infection rate in a small series (36). Primary closure of wounds that can be adequately cleansed in well-vascularized areas should not present a problem. The typical small forehead laceration that is caused by a playmate's tooth is an example of a bite wound that should not be closed unless the wound is surgically extended for proper cleansing (36).

Dog Bites

Most animal bites that are considered for suturing in the ED are inflicted by canines. These wounds are assumed to be contaminated although it has been stated that meal-eating (as opposed to meat-eating) dogs do not have sufficient oral bacteria to create an inoculum at the level of 10^5 bacteria/g of tissue (9). As with human bites, dog bites to the hand are at higher risk for infection regardless of the use of antibiotics (35, 38, 39).

If coupled with excellent wound care and meticulous closing technique, suturing of facial dog bite wounds can safely be accomplished without using antibiotics (40). In a repair of 145 recent (less than 6 hours old) facial dog bites in 45 children after pressure irrigation with normal saline solution and wound edge excision, an infection rate of only 0.4% was reported even though no antibiotics were administered (40).

Regarding primary suturing of dog bite wounds in the face and other areas, the clinician must again consider the vascular supply and the ability to adequately clean the wound (32). Puncture type wounds can be expected to have a poor outcome if sutured, whereas, large dog bite lacerations that can be adequately cleansed generally do well. Dog bite lacerations of the face, facial structures and scalp should generally be repaired primarily if cosmetically indicated (32, 39).

Other Animal Bites

Wounds caused by cats are generally not considered for suturing as they are usually puncture type wounds. Lacerations caused by monkeys have a notorious reputation based on anecdotal reports, whereas those caused by large herbivores such as horses will be associated with significant crush injury (32). Recommendations on primary closure of these wounds are lacking given their relative infrequency.

Foreign Bodies and Wound Closure

The presence of a nonirritant foreign body such as a small piece of metal or glass is not a contraindication to primary wound closure (41). Such wounds can be closed and managed expectantly if the foreign body is difficult to remove, is not in a critical area (e.g., joint space or near a vital structure), and is not positioned so that it would be a likely source of ongoing irritation for the patient. Certainly, the patient and family should be informed of the presence of a foreign body and the rationale for the planned course of action.

Irritant foreign bodies such as wooden splinters or thorns should be removed at the time of presentation to avoid infectious complications (41) (see also Chapter 113). The presence of even minute amounts of soil in a wound invites infection, and wounds with suspected soil remaining should not be closed primarily (11).

Gunshot and Stab Wounds

Low velocity gunshot wounds that do not damage underlying structures can be managed on an outpatient basis. The traditional care of these wounds includes open treatment (no sutures) and basic wound care without using antibiotics (42). These wounds generally heal well without antibiotic therapy despite retained metallic fragments in the wound (42).

Stab wounds must be evaluated for depth and involvement or penetration of underlying structures before closure. This frequently necessitates surgical consultation. These wounds may be categorized as puncture wounds or simple, sharply incised lacerations. In the latter slashing type injury, such wounds may be closed as any other. Deeper puncture type injuries are traditionally managed in an open fashion (Chapter 112).

Dead Space

Eliminating any pocket in the depths of the wound that could collect blood or serum and thereby potentiate infection often is accepted as an essential step in wound management. This must be distinguished from the technique of a layered closure to decrease tension on the wound edge, which has cosmetic advantages (11, 12) Although theoretically useful, the suture closure of dead space to decrease infection has not been shown to be beneficial and may actually be detrimental (49–51). In a rabbit study using wounds inoculated with bacteria, it was demonstrated that, although dead space increased the rate of infection, suture closure of this dead space actually worsened the situation (50). It also is recommended to avoid sutures in the fat layer (12, 49, 51).

EQUIPMENT

The emergency physician frequently accepts the available equipment for wound repair in the ED as a *fait accompli*. Yet the frequent use of this equipment and the important nature of the task require that high quality instruments be available when needed. The clinician must accept nothing less. Basic surgical tool requirements useful for wound repair are listed below.

Needle holder—appropriately sized for suture needle. An excessively large needle holder will flatten a small needle after a few uses.

Nontraumatic tissue forceps—with no hooks to avoid crushing tissue. An alternative to using forceps is single- or double-pronged skin hooks (43).

Tissue scissors—a sharp, tightly cutting pair is essential for debridement.

Hemostats—these may be useful in situations when bleeding vessels will require ligation.

Scalpels—No. 10 or 15 blade may be necessary for sharp debridement.

Sterile drapes—an adequate amount to keep the wound area sterile. In the repair of facial wounds the hole in the drape should not be so small as to obscure useful landmarks (30). Facial drapes can be foregone if they cause excess anxiety in a child.

Sterile gauze—a ready supply of a sufficient number is frequently overlooked in setting up for laceration repair.

Sterile gloves and mask—important to reduce contamination of the wound by the clinician (11, 43). These items and a facial splashshield also should be considered necessary for protecting the clinician.

Light—an adequate light source is essential and will preferably be directed into the wound unobstructed from above.

Bed—the patient and bed should be positioned in a way to maximize comfort of both the patient and the clinician during the procedure. Using arm extensions and pillows should be considered and the height of the bed should be raised to a workable level.

Suture material (11, 43-46)—generally divided into absorbable and nonabsorbable based on the retention of tensile strength less than or greater than 60 days. Using catgut as an absorbable suture is no longer recommended. Two general types of synthetic absorbable sutures, Dexon® and Vicryl®, are both excellent choices for general wound repair.

Several types of nonabsorbable sutures are available for percutaneous suturing; however, the general choice for emergency physicians will be a nylon (Dermalon®, Ethilon®) or a polypropylene (Prolene®) suture. The monofilament sutures are preferred over braided or multifilament sutures which are thought to increase the risk of wound infection by providing interstices for bacteria to be shielded from leukocytes. A lower coefficient of friction allows a suture to smoothly pass through tissue. This same property, however, lessens the stability of the knot. Most synthetic sutures possess a low coefficient of friction and therefore the clinician should use at least four throws when tying knots with this material.

Silk is more reactive than synthetic suture material which limits its usefulness for general wound repair. The relatively soft feel of silk and its workability make it a consideration for repairs of the eyelid or mouth. In these areas silk sutures are usually removed in a few days thus lessening the reactivity problem.

Generally, the smallest size suture acceptable for the repair is recommended to reduce the amount of foreign material in the wound. The size of nonabsorbable sutures most commonly used in the ED run, in increasing order of diameter, from 6.0 to 3.0. Facial repairs will be conducted with 5.0 or 6.0 sutures, whereas 4.0 is commonly used for other areas. Use of 3.0 suture is usually limited to the scalp or areas of significant tension such as over joints. However, most scalp injuries and wounds over joints can be adequately managed with 4.0 suture. Absorbable sutures will remain in the wound for a long period and therefore using 5.0 is generally recommended although 4.0 may be advisable in areas with increased tension.

Needles—the reverse cutting needle is the best choice for general wound repair in the ED. This needle has the main cutting edge situated on the outside of the curve of the needle so that the cut is made away from the wound edge, which prevents the suture material from further cutting into the tissue along the path of the needle cut.

PROCEDURE

Wound Preparation

Anesthesia

Adequate anesthesia and a cooperative patient are essential for proper wound preparation (25). Principles of wound anesthesia and cleansing are covered extensively in Chapters 37 and 110. Using small gauge needles for the slow injection of a buffered anesthetic deep in the wound coupled with distraction by applying pressure around the wound will generally allow for reasonable cooperation by the patient (15). Complete anesthesia of the affected area must be accomplished before wound manipulation. It is the fault of the one providing anesthesia, and not the patient, if this is not satisfactory. If anesthesia is inadequate, the clinician must retreat and start over to ensure a wound repair that is the least distressing for both the patient and family. The repair of lacerations is perhaps the most common indication for using conscious sedation in the young child (Chapter 35).

Exploration

Exploration of all wounds with proper hemostasis to allow for complete visualization is mandatory to detect underlying injury or foreign bodies. Hemostasis usually can be achieved by local pressure or by using a blood pressure cuff inflated above systolic pressure in an extremity that has been elevated for 1 minute before cuff inflation (1[illegible]). It is essential to explore wounds of the extremities through their full range of motion and to be particularly meticulous in examining them in the position of wounding. For example, the typical knee wound is approached with the patient's leg in full extension when most injuries occur in some degree of flexion. Exploration of injuries to the plantar surface of the foot may be facilitated by turning the (prone) patient around on the stretcher and elevating the foot into view with the head of the stretcher.

The clincian should have little hesitation to extend a wound using a scalpel if needed for proper wound exploration. The resulting added length of wound should heal in a eptable fashion given the sharply incised nature of the wound extension. Once a foreign body is found within a wound this should be a signal to the clinician that more lies in wait for discovery. If the clinician is contemplating primary repair, he or she must continue to explore the wound until assured that no soil or irritant foreign bodies remain (11, 41).

Debridement

Removing devitalized or heavily contaminated tissue from a wound is a fundamental principle of wound care (9, 11, 25, 27). Sharp debridement of a contaminated wound may allow closure of a wound that would otherwise be treated with delayed primary closure (17). Debridement may be accomplished by excising the entire wound, sometimes referred to as wound ellipsing, or in a more selective fashion. Wounds that are amenable to excision are those in areas lacking vital underlying structures and where sufficient excess tissue is available to allow closing the wound without undue tension (11).

Although it decreases the likelihood of infection, excision can worsen the eventual cosmetic result. Excision should generally follow the RSTL as described previously (Fig. 111.2) (14, 47, 48). In fact, it is wise to excise only those wounds that can be easily done in a manner that will closely parallel the RSTL (11, 14). Excision performed on a jagged wound that is not parallel to the RSTL may produce a straight edge but will have a wide scar due to the tension on the wound. The same jagged laceration with multiple components running in different directions will be essentially a natural Z-plasty (14). Such a wound will have some segments following the RSTL and will likely heal in a more acceptable manner than the "clean" excision (11, 14).

Debridement of facial wounds should be conservative (14, 30). Given the excellent blood supply of the face, it is difficult to be sure tissue is truly devitalized. It is wiser to refrain from debridement rather than to sacrifice tissue that may live (14). Loss of tissue is the most significant limiting factor to the success of later plastic scar revision (47). An important cosmetic structure such as the philtrum should never be debrided (30).

If a wound is excised the effect of the natural contraction of the wound on surrounding structures must be anticipated. For example, a wide horizontal excision on the forehead may heal with a thin scar but cock the eyebrow on that side (30).

Certain areas are less amenable to excision and debridement. These areas include the nose, lip, hand, forearm, anterior lower leg, and the foot (12, 17, 27). When excising in a hairy region such as the eyebrow, all cuts must be angled parallel to the direction of the hair shafts and follicles to avoid excess follicle loss and a wide hairless scar (30, 47).

The technique of wound excision involves making a smooth, elliptical cut around the wound area to be excised (Fig. 111.3). This usually will, but does not necessarily, encompass the entire wound. It is recommended that the eventual length of the excision exceed the width by a factor of three (12). It is wise to mark the desired path of the skin cut. Two general methods are recommended for completing the excision. The skin can be scored with a scalpel and the cut completed with a pair of sharp tissue scissors (12)

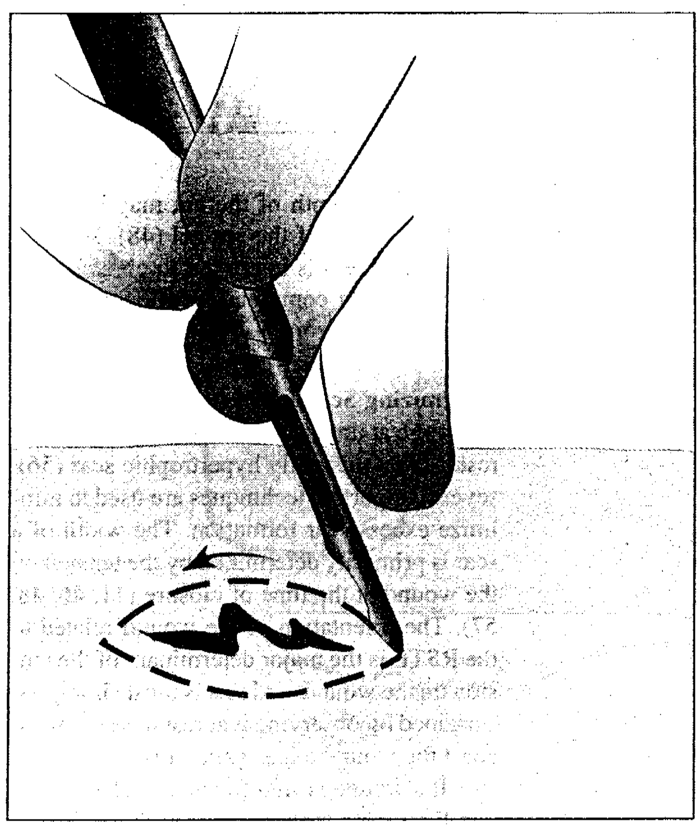


Figure 111.3.
Elliptical incision of a jagged laceration.

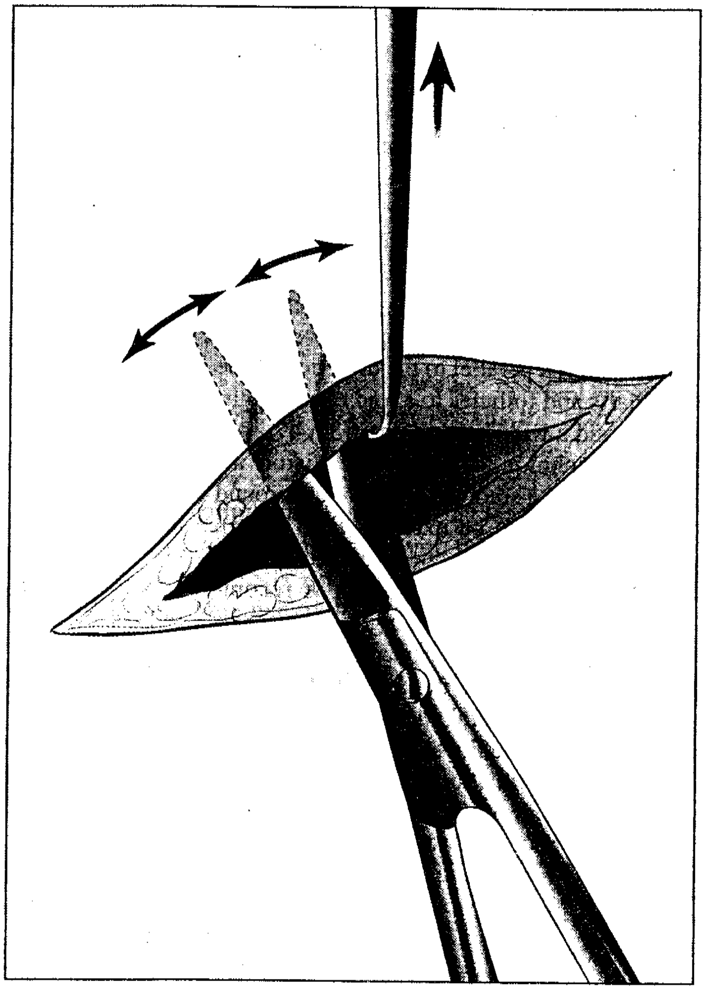


Figure 111.4.
Undermining a wound reduces the degree of tension present after the repair.

or the entire depth of the cut may be made with one stroke of the scalpel (48). With either technique it is important to obtain a perpendicular cut completely through the dermis.

Minimizing Scar Formation

Although at times even the best of efforts will result in an unsightly hypertrophic scar (56), several important techniques are used to minimize excess scar formation. The width of a scar is primarily determined by the tension on the wound at the time of closure (11, 46, 48, 57). The orientation of the wound related to the RSTL is the major determinant of the tension on the wound, and this is most simply ascertained by observing it at rest to see how far apart the wound edges gape (49).

If a wound is significantly angled or perpendicular in relation to the RSTL it will likely heal with a wide scar (11, 30, 48). As mentioned, this is a primary consideration when contemplating wound excision. It is important to remember that the RSTL in the individual patient do not always follow the book (47, 49). The wrinkle lines which are so useful in adults to determine the orientation of the RSTL are not as evident in children. A practical technique to determine the orientation of skin tension is to simply pinch the skin and observe which direction has the longest furrows and, hence, the least tension (56).

When a wound is under tension certain methods are used to counteract this influence and reduce the eventual width of the scar. The primary method to counteract tension is to place subcutaneous sutures before percutaneous sutures (12). Techniques such as Z-plasty and W-plasty to reduce the tension on less favorably placed wounds are used by plastic surgeons and their performance is beyond the scope of this chapter (14, 30, 47). A relatively simple technique for reducing tension is to undermine the adjacent soft tissue to decrease the natural static tensions of the surrounding skin. A paucity of clinical studies on this technique exist; however, a wound study in a porcine model found that undermining generally decreased the forces required to close a wound (58).

Undermining is generally carried out in the plane of the subcutaneous fat for a distance of several millimeters or up to twice the width of the wound (Fig. 111.4) (12, 48). A pair of scissors or a scalpel is used to loosen the subdermal fatty tissue. The goal is to allow the skin edges to be brought together with very little tension. A note of caution has been raised about using undermining in contaminated wounds (11). The disruption of blood supply potentially caused by this largely unproven technique may lead to an increased risk of infection and offset any cosmetic improvement (11).

Simple scars that are most visible are characterized by abnormal color or an uneven surface which casts shadows (12). Good technique can help minimize the latter problem by producing a flatter scar through eversion of skin edges, matching skin heights, proper suture placement, and care in handling tissue.

Wound edges must be everted at the time of closure (12, 46, 48). Eversion is accomplished by placing the percutaneous suture so that its depth is greater than its width (Fig. 111.5) (12, 46). Alternatively, a mattress suture can be used to produce eversion of the wound edge (12, 48). The difficulty with mattress sutures, however, is their tendency to cause ischemia of the wound edge (9). As discussed later in this chapter, using the lateral mattress suture for eversion may be preferable in this situation (48).

Absolute matching of the skin heights must be accomplished when the wound is sutured (12). Going in and out of each wound edge separately, using two passes with the suture needle, is the best strategy in wounds that are uneven (11). For precise approximation of the wound edges in jagged or stellate lacerations, meticulous placement of individual sutures is recommended (11, 46).

Most scar formation is a natural reaction to tissue injury and therefore the tissue to be repaired should be handled as gently as possible (17, 48). This can be ensured by using noncrushing clamps and by using only the fingers or skin hooks to handle the skin edges (17, 43, 48).

It is important for the clinician to be aware of circumstances when unsightly scarring is likely. For example, curved or U-shaped flap lacerations, often termed trap door lacerations, tend to yield poor results by virtue of the natural contraction of the wound to a point central in the flap (43, 47). When these are encountered in cosmetic areas, such as the forehead, it is wise to consider referral or to warn the parents of the likely need for revision.

Suturing Techniques

General Principles

Key principles to remember regarding the use of sutures include:

1. Every suture is a foreign body and the least amount of sutures should be used for the shortest time period that is sufficient. Corollaries to this include using deep sutures only when necessary, limiting the number of knots in a buried suture to three, and using the smallest size

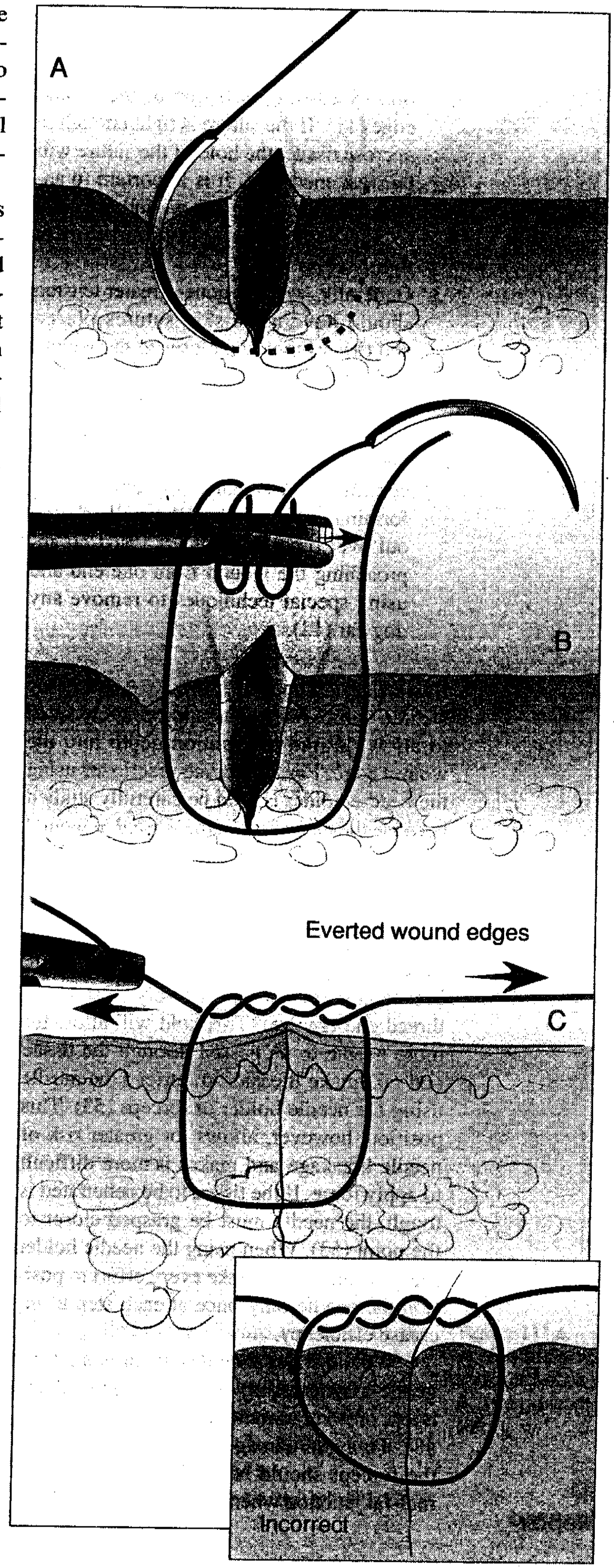


Figure 111.5.
The simple interrupted skin suture secured with an instrument tie.

and number of sutures necessary for percutaneous placement (44, 45, 49).

2. Tight sutures increase the risk of infection by causing ischemia of the wound edge (11). If the suture is tight enough to necrose tissue, the hold of the suture will be weakened (52). It is important to anticipate swelling in the wound area and to approximate the tissue rather than tightly close it.
3. Generally, wounds under greater tension should have more skin sutures placed and these should be closer to the wound edge (12).
4. Two general approaches to sewing the wound are recommended. Some authorities advocate dividing the wound with a central stitch because any extra tissue forming a "dog ear" will usually flatten out over time (48). Others insist on approaching the wound from one end and using special techniques to remove any dog ear (12).

Basic Use of Tools

Needle choice should be appropriately sized to allow desired penetration depth into the wound edge. For the novice practioner using the needle holder should be carefully studied because the majority of time wasted in wound repair relates to its use (53). The needle is best held perpendicular to the needle holder and the position where the needle is grasped can be varied according to the clinician's needs. For soft tissue repair it is generally best to grab the needle relatively close to the thread end (swage). This hold will allow for more needle to be passed through the tissue and will make it easier to retrieve the needle using the needle holder or forceps (53). This position, however, allows for greater risk of needle breakage and makes it more difficult to apply force. If the tissue to be penetrated is tough, the needle must be grasped closer to the point (53). When using the needle holder the clincian should make every effort to position the needle only once at each step to increase efficiency.

Wound edges should be manipulated in a gentle manner using only the fingers, a skin hook, or nontraumatic tissue forceps (17, 43, 48). To avoid damage to the epithelial layer the forceps should be used to grasp the dermal-fat junction when suturing (12). The needle should be retrieved only with the needle holder or a pair of forceps to avoid injury to the clinician. For similar reasons, the clinician should not use the fingers to help push the tissue over the needle.

Types of Stitches

Simple Interrupted Skin Sutures

Because the simple interrupted skin suture is most commonly used, this technique should be mastered first. As mentioned previously, it is essential to obtain eversion of the wound edges to minimize scar formation. Eversion means that the wound edges are rolled slightly outward with the two edges of the wound lined up exactly. To achieve wound edge eversion the path of the needle must be directly down or angled slightly away from the wound edge (12, 46) (Fig. 111.5.A). Additionally, the depth of the suture path must be greater than the width. The entire depth of the wound edge can be pulled perpendicular to the skin by grasping the fat-dermal junction with forceps and driving the needle straight down (12). The needle must trace an equal path through both sides of the wound to ensure accurate apposition of the wound. This is most easily achieved by pulling the needle though one side and out of the wound before reentering deep in the opposite side of the wound.

Another technique described for obtaining wound edge eversion is to pucker the wound edges in an everted manner with finger and thumb pressure before passing the needle completely through both sides of the wound (43).

Knot tying can be a source of frustration but is easily mastered with practice. The general technique most useful for knot tying [illegible] the ED is the instrument tie (Fig.111.5). Th[illegible] is best accomplished by pulling most of [illegible] suture through the wound so that only a fe[illegible] centimeters of thread are exposed at the fi[illegible] insertion site. At this stage, the remain[illegible] longer length of thread attached to the nee[illegible] is grasped in the nondominant hand. The n[illegible]dle holder, grasped in the dominant hand[illegible] placed across the longer (needle) length[illegible] thread, and the thread is then looped tw[illegible] over the tip (Fig. 111.5.B). The needle ho[illegible] then grasps the short (free) end of suture[illegible] pulls this away from the side of the wo[illegible] initially entered, which will lay the do[illegible] ot flat (Fig. 111.5.C). The knot is tightened that the skin edges just come together. Further tightening beyond this point risks wound edge ischemia. The process is now reversed, with the needle holder again placed across the longer length of suture which is then looped twice under the tip. The needle holder then grasps the free end of the suture, and returns to the initial needle entry side of the wound, while the needle length of suture is carried back to the initial needle exit side of the wound. This alternating "over and under" method of tying results in a surgeon's knot. For monofilament sutures this should be repeated first in the over and then in the under manner for a total of four throws to secure the knot.

Most skin repair will be performed with monofilament sutures that, due to their low coefficient of friction, allow for further loosening or tightening of previously tied knots (45). This takes some pressure off the need for perfect wound edge approximation at placement of the first throw in tying. This same property, however, can cause knots to loosen excessively when attempting to secure them. To combat slippage of the first knot a locking technique may be used (53). In this technique, after the first double knot is laid flat, the pull of the hands is immediately reversed to lock the knot (53). To retain the lock, the next throw must be placed without tension on the segments.

Excess knots will actually weaken the suture and should be avoided (46). The ends of the suture should be cut long enough to allow easy handling for removal.

Subcutaneous Sutures

The primary reason to place subcutaneous sutures is to counteract tension on the wound and thus decrease the width of the subsequent scar. Using synthetic absorbable sutures to close the deep tissues will decrease the tension on the wound (11, 12, 48, 49). Placing such sutures in the dermal layer is especially important; however, the fascial junction surrounding muscle also is important to close (11, 12, 43, 49). It is essential in repairing injured muscle that the fascia is incorporated in the suture as the muscle itself will not hold a stitch (30, 43). When deep sutures are placed in the dermis in cosmetic areas it is generally recommended that the knot be buried (i.e., pointing downward toward the base of the wound) to keep as much foreign material as possible away from the healing wound edge (12, 46, 48). Using deep sutures in any wound at risk for infection must be undertaken cautiously or not at all (25, 54).

The fascial layer can be closed with sim-

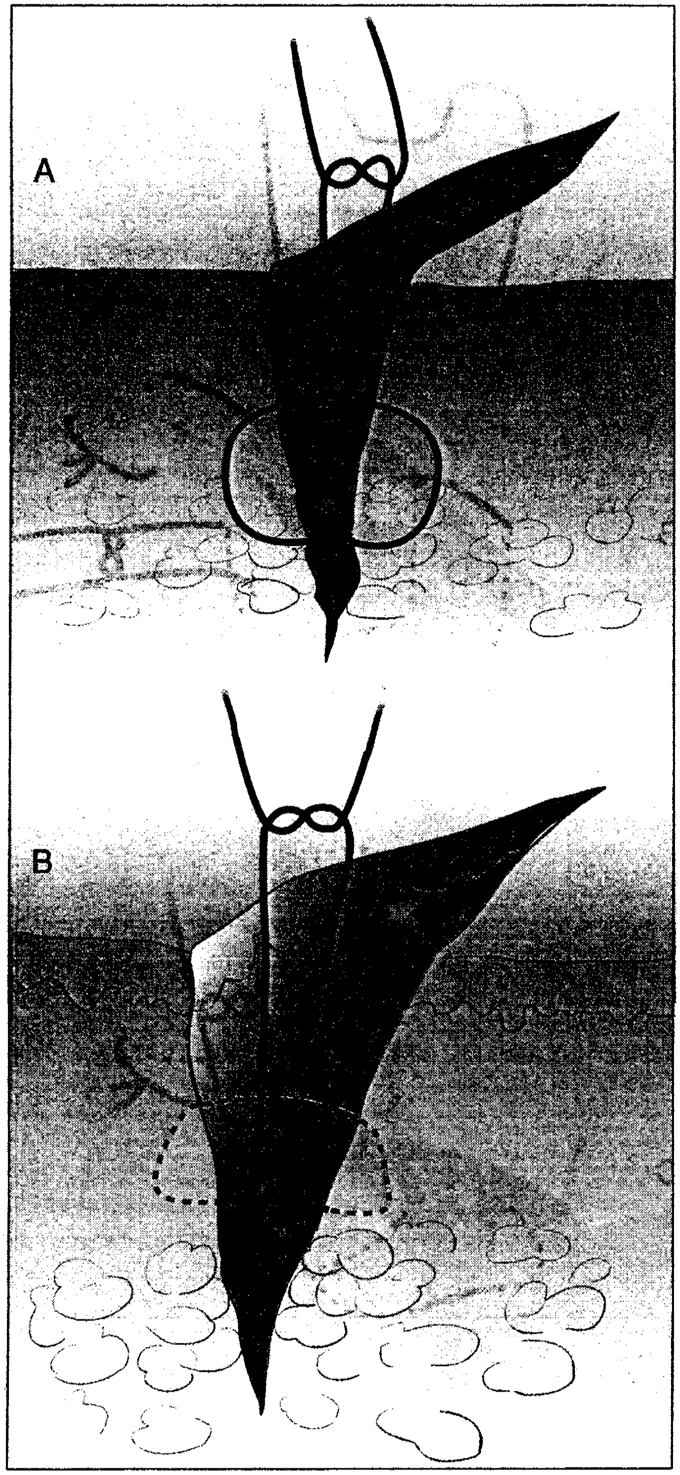


Figure 111.6.
A. The buried subcutaneous suture.
B. The horizontal dermal stitch.

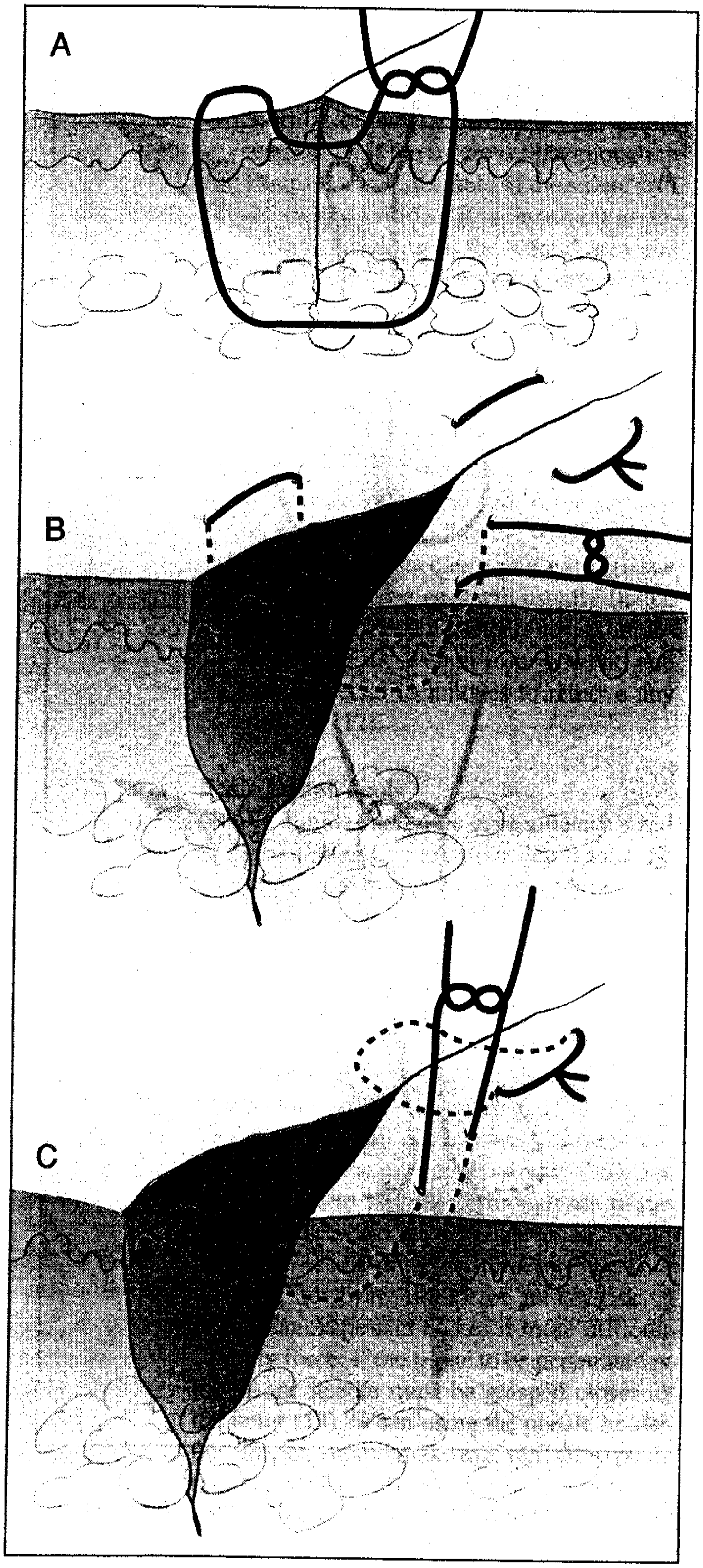


Figure 111.7.
Mattress sutures.
A. Vertical mattress suture.
B. Horizontal mattress suture.
C. Half-buried horizontal mattress suture.

ple sutures, but subcutaneous sutures in the dermal layer will need to be inverted with the knot buried in areas where the skin is thin or cosmetic appearance is important (12, 46, 48). The initial insertion point of these subcutaneous sutures will be in the depths of the wound, typically at the fat-dermal junction (Fig. 111.6.A). Exposure of the correct entry point can be facilitated by using tissue forceps or a skin hook. The needle is rotated up through the tissue to exit in the dermis. At this point it is essential to pause and make sure that the second insertion point in the opposing dermis is at an equal vertical and horizontal level with the exit point of the first pass. Once this is ascertained the downward pass of the suture becomes a mirror image of the first pass, exiting at the same level as the original insertion. The needle end and free end of the suture should be on the same side of the loop. The knot is then tied, generally with only three throws to minimize suture material in the wound (45).

A simple but useful variation of the traditional subcutaneous suture is the horizontal dermal stitch (Fig. 111.6.B) (43). In this technique the dermis is aligned by placing a simple stitch in a horizontal plane. The loop and knot are at the same level in the subcutaneous tissue. This suture provides a nice approximation of the wound edge before skin closure but carries the disadvantage of an inability to bury the knot. This suture is most practical when nearing the end of a subcutaneous closure when room is limited to maneuver for an inverted suture.

Interrupted Mattress Sutures

Three basic types of mattress sutures are the vertical, the horizontal, and the half-bur[ied] horizontal (Fig. 111.7). These technique[s] useful to provide eversion of the wo[und] edges. The traditional vertical mattress su[ture] involves taking a large deep course with first pass of the needle and then tak[ing] smaller stitch close to the wound edg[e] knot is then tied on the side of the woun[d] tered initially. It is important to avoid th[e] dency to apply excess tension when these knots. Notably, the vertical matt[ress] ture may cause ischemia of the woun[d] (9). The horizontal mattress suture cl[oses] greater length of wound than the vertica[l] tress suture but usually results in less a[...]

ɪroximation of the wound edges. The half-ɪied horizontal mattress stitch offers some ɪantages in that the number of skin punc-ɪs is halved and less tension is on the free ɪe of the wound opposite the knot (43).

ɪner Stitch and V-Y Advancement Flap

ɪ corner stitch is simply a variation on the f-buried mattress suture (Fig. 111.8). ɪen applying this type of suture it is often ɪe to extend the apex of the V to form a Y, ɪch will release some of the tension on this ɪner (43). The extension into a Y shape can complimented with undermining as de-ɪibed previously to further decrease ten-n.

ɪtinuous Skin Sutures

ɪ sole reason to use a continuous stitch is ɪave time. This method poses some poten-problems as breakage of one point may ɪavel the entire stitch (43). These sutures ɪ may risk ischemia of the wound edge or ɪy formation of stitch marks if they are ɪed too tight (43, 54). Ischemia is more ɪly to be a problem if an interlocking ɪthod is used. Some authorities feel that ɪtinuous sutures are problematic if focal ɪund infection occurs; however, the suture ɪ be cut and unwound from the infected a and secured with tape (54). This method generally recommended for relatively ɪight clean wounds under little tension ɪ). Others prefer interrupted sutures for ɪmetic areas. Careful placement of the in-ɪidual sutures in a continuous stitch how-ɪr, can yield an excellent result (12).

The most useful continuous stitch is the ɪple running stitch (Fig. 111.9.A), which is ɪted by making a simple interrupted stitch ɪ only cutting the end of thread not at-ɪhed to the needle. The physician then per-ɪms sequential passes perpendicularly ɪoss the wound the same distance apart as ɪmally placed interrupted sutures. Care is ɪen to take bites of equal depth from side to ɪe. After each pass the length of thread ɪuld be pulled to close the wound and the ɪcement evaluated before proceeding to the ɪt pass. If the placement is unacceptable needle can be backed out through the ɪch site and the pass reattempted. Slight ɪsion can be maintained on the thread that already been used to suture so that the entire wound does not have to be reapproximated after each suture. Once the desired length is closed the running stitch is most simply ended by reversing the direction of the needle pass using an entry site close to the previous exit site. This allows a narrow loop to be formed on one side that can be tied with the final pass to the opposite side (Fig. 111.9.A).

The continuous interlocking stitch is conducted in virtually the same manner as the simple running stitch except that the needle is

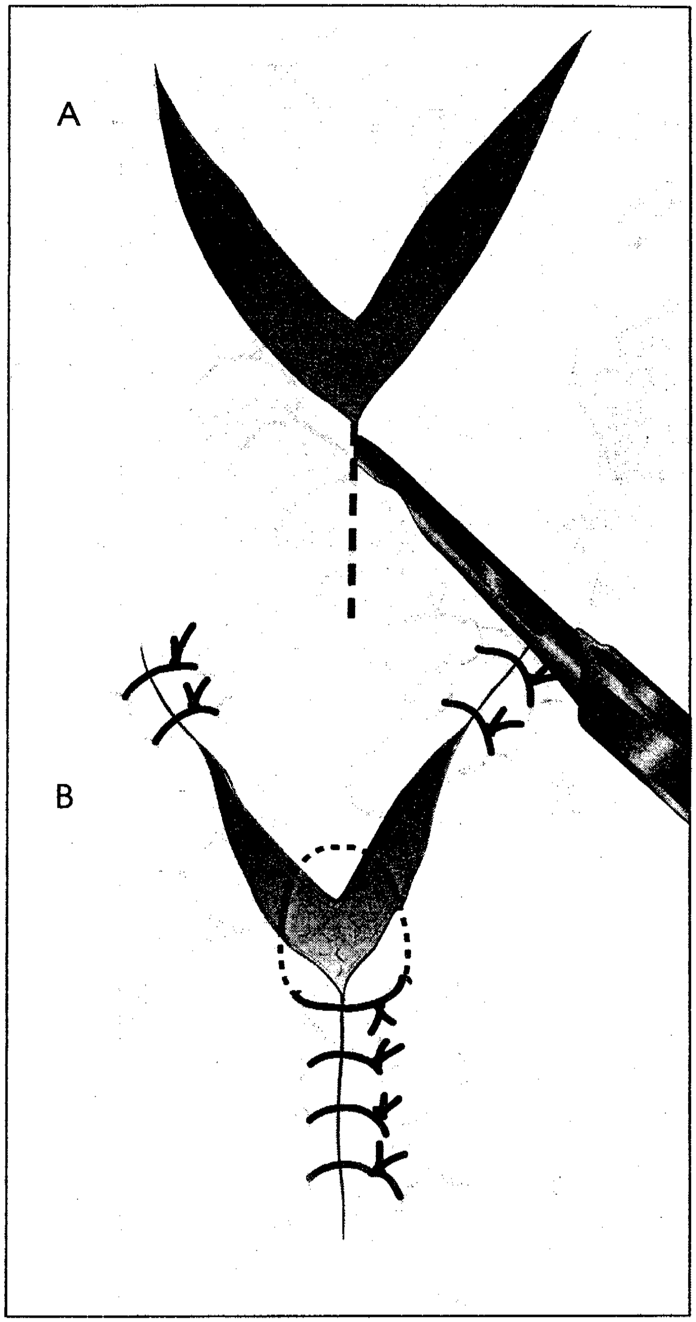


Figure 111.8. Corner stitch and V-Y advancement flap. **A.** Extension of the wound at the apex of the V. **B.** Half-buried horizontal mattress stitch and simple interrupted stitches in the repair of a Y-shaped laceration.

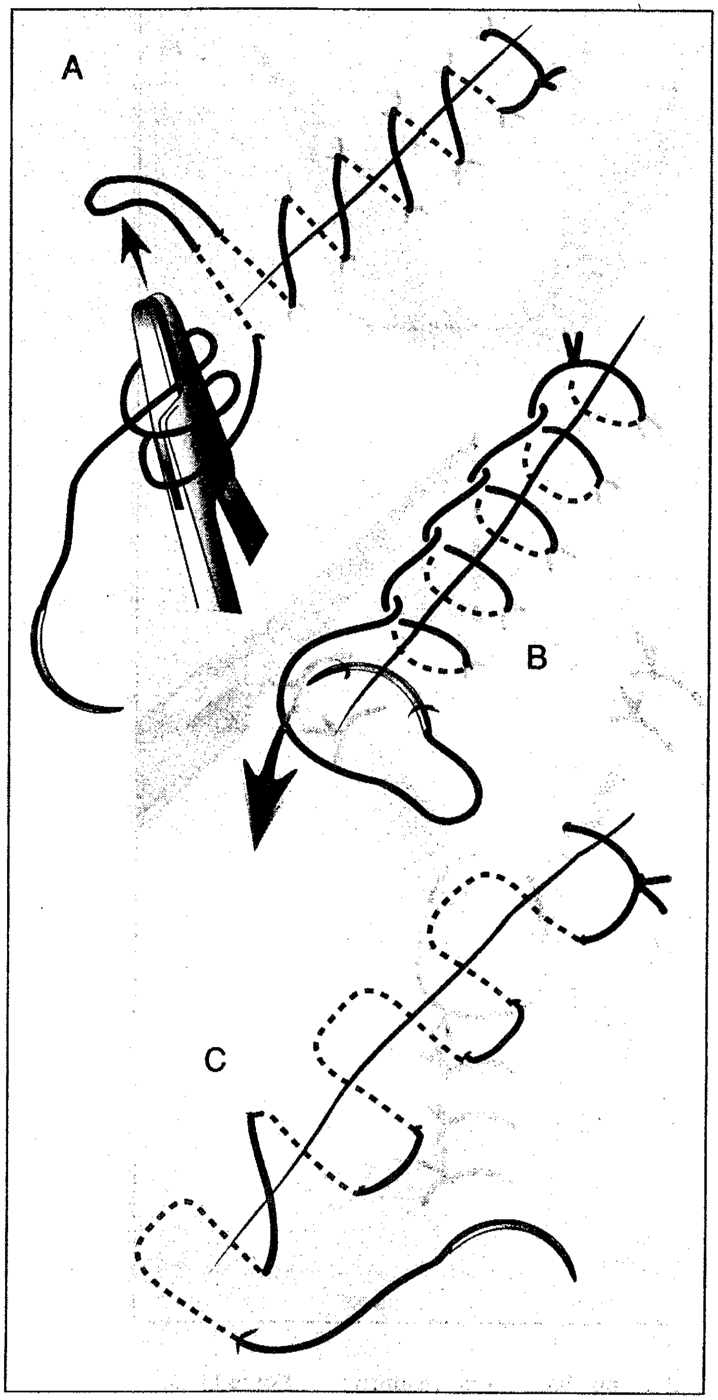


Figure 111.9.
Continuous skin sutures.
A. The simple continuous running skin stitch.
B. The continuous interlocking skin stitch.
C. The running lateral mattress stitch or continuous half-buried horizontal mattress stitch.

passed through a loop created by pulling the length of thread down in the direction the clinician is suturing (Fig. 111.9.B). A variation of the running stitch that uses the eversion advantage of a mattress suture is the running lateral mattress stitch (Fig. 111.9.C). It is recommended in this technique that a loop be intermittently run over the top to facilitate removal of this suture (48).

The running subcuticular stitch usually does not offer much time-saving advantage as it requires precise placement from side to side. However, it does prevent the occurrence of stitch marks and can be left in place for 2 to 3 weeks (47). These features make it a useful technique in patients prone to keloid formation and in situations such as young children when repeat trauma to the area is a concern (43, 48). It is generally not recommended to use a running subcuticular stitch in wounds at risk of infection (11, 55). This technique should generally not be used in a wound under significant tension before skin closure (43).

This technique is often used for cosmetic closures because of the lack of potential for stitch marks; however, exact alignment of the vertical heights of the wound is difficult (4[illegible]). Furthermore, in cosmetic areas, sutures are generally removed in 3 to 4 days, well before the risk period for stitch marks (25, 46, 56).

This suture is usually begun by passing the suture through the skin at one end of the wound to exit in the dermis (Fig. 111.[illegible]). The wound is then closed by making small passes, usually less than 1 cm in width, in alternating sides of the wound in the dermal layer parallel to the skin surface. To ensure adequate alignment, each pass is usually begun slightly behind the exit point of the previous pass (43). Obviously, placement of each pass must be at the same level of depth throughout the wound to ensure a good [illegible] If the clinician must sew a long distance, [illegible] advisable to bring the suture up to the surface on occasion to allow for easier removal [illegible] 111.10). Using skin tapes compliments [illegible] technique (11). The clinician can end the suture by bringing it out through the skin surface. The two ends of exposed suture [illegible] taped in place using skin adhesive. If the clinician is worried about the security of the repair, he or she can initiate the process with [illegible] interrupted suture and end with a lock-back placement as performed with the running skin suture (Fig. 111.9.A) to secure [illegible] free ends.

Alternatives to Suturing

Staples

The availability of relatively inexpensive disposable skin staplers has increased the [illegible] this method of wound repair in the [illegible] perimentally, staples produce less inflammation in wounds than sutures while yielding a similar tensile strength (59). The major advantages in using staples are in time saved and in a decreased risk in exposure of the clinician to blood-borne diseases (60). Staples are particularly useful in long linear lacerations produced by slashing with a knife or razor edge. Some authorities recommend staples only for sharply incised wounds (61). Clinical reports, however, indicate their usefulness in other situations (60, 62).

Clinically, staples have been most commonly used for closing scalp lacerations (60, 62). Using staples is not recommended in the face for cosmetic reasons, in the hands and feet for comfort reasons, or in the scalp of a patient who will undergo complex cranial imaging (61, 62).

The wound is prepared for staple placement in the same manner as for traditional suture placement. This includes using subcutaneous sutures when needed to reduce tension (61). Placement of the staples is best achieved when an assistant everts the wound edges with tissue forceps or finger pressure.

A staple remover is a simple device that is often needed to correct inaccurate placement at the time of repair. This can then be given to the patient to bring to the follow-up visit for staple removal. Staples are generally left in place for a period similar to sutures in the same area.

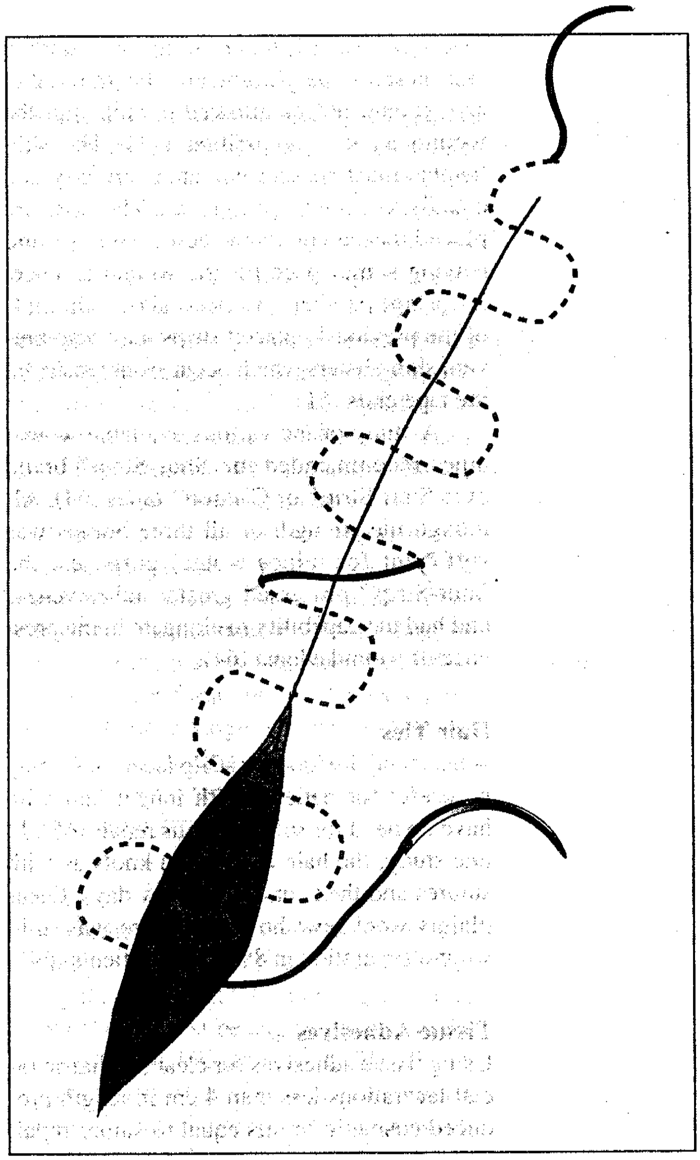


Figure 111.10. Continuous subcuticular stitch.

Wound Tapes

Using wound tapes as the sole method of primary wound repair is acceptable for linear lacerations under minimal tension (11, 61). Their use in pediatric emergency care is common. One study reported that 20% of lacerations in children were closed with wound tapes (20). If the wound can be managed using only a topical anesthetic and does not require anesthesia by injection for cleansing or debridement, tapes can be applied painlessly (56). Wound tapes also are useful in reinforcing or refining other repairs including subcuticular methods (11). To avoid stitch marks in cosmetic areas, sutures can be removed in 2 to 3 days and replaced with skin tapes (48). If sutures are found to be under tension at any time it is recommended to remove them and apply skin tapes (48, 49).

Because wound tapes do not cause the inflammatory process associated with suture placement it is not surprising that taped wounds are less likely to become infected than sutured wounds (16, 63). Skin tapes generally will not allow for the meticulous approximation required with stellate wounds and therefore such wounds generally require percutaneous sutures (11). Wound tapes are of no use in areas that are naturally moist or excessively hairy such as the scalp, axilla, palms, and soles (11, 61). Lacerations with surrounding abrasions present a problem if no sufficient uninjured skin is proximate to the wound to allow for application of an adhesive to the skin.

After wound preparation, the technique of tape application is simple. This requires cleansing, drying, and applying an adhesive (e.g., tincture of benzoin) to the surrounding skin before tape placement. The skin adhesive should not be allowed to spill into the wound as it is an irritant (11). The skin heights must be approximated carefully and equally to ensure a good result. The tapes are placed perpendicularly across the wound leaving some space for the wound to ooze. Extra tape parallel to the wound over the ends of the previously placed strips may help prevent skin blisters which occur from tension at the tape ends (61).

A study of the various available wound tapes recommended the Shur-Strip® brand over Steri-Strip® or Clearon® tapes (64). Although the strength of all three brands was sufficient for minor wound purposes, the Shur-Strip® possessed greater adhesiveness and had the capability to elongate in the presence of wound edema (64).

Hair Ties

A hair tying method for scalp lacerations may be useful for patients with longer hair who have no need for subcutaneous repair (65). In one study, the hair was tied in knots as with sutures and then cut out in a few days. Complaints were few; however, there was mild wound separation in 8% of the patients (64).

Tissue Adhesives

Using tissue adhesives for clean, pediatric facial lacerations less than 4 cm in length produced cosmetic results equal to suture repair (66). The tissue adhesive method also was faster and less painful than sutures (66). Currently, a preparation for this technique is not FDA approved for use in the United States.

Delayed Primary Closure

The technique of delayed primary closure is based on experimental studies of contaminated wounds. In one study, the infection rate of experimentally contaminated wounds was high if they were closed on the first day but became uncommon in these wounds if closure was delayed until after 4 days (69). This technique will not be used as often in pediatric wound care because heavily contaminated and crush wounds from street brawls, farming, and industrial accidents are infrequent in this population (19).

It was previously recommended that hand wounds undergo special consideration for delayed primary closure, but this is unnecessary for most civilian hand wounds (22). Additionally, this technique may lead to desiccation of vital hand structures.

The wound that is to undergo delayed primary closure is initially approached in a manner similar to other wounds. Adequate anesthesia is required for cleansing and debridement. The wound cavity is then filled with a sterile, fine mesh gauze and covered using a bulky dressing. The wound is then left completely undisturbed for 4 to 5 days unless pain, fever, or other signs indicate potential wound infection (17, 49, 70). At 4 to 5 days the wound, if uninfected and free of debris and devitalized tissue, can be approximated with sutures or skin tapes. These wounds will heal with excellent tensile strength as the injury will just be entering the active phase of regeneration (70).

To avoid the need for repeat anesthesia of the wound, sutures can be placed in healthy tissue away from the wound edge at the time of the first visit and then tied at the time of follow-up (17, 49). Alternatively, by day 4 or 5, rather than just apposing the wound edges, the clinician may opt to sharply incise both edges to create a freshly cut surface for approximation (17). This delayed wound excision is primarily used to improve the cosmetic result, as a direct closure should heal without problems.

Approach to Specific Areas

Scalp

Scalp wounds are common and generally heal in an uncomplicated manner due to excellent vascular supply. Emergency physicians must not be cavalier in their approach to these wounds as significant underlying [illegible] may be present. Additionally, a sub[illegible] wound infection can cause serious morbidity (43). It is wise to explore all scalp wounds both visually and digitally to exclude the presence of a fracture or foreign body. [illegible] should be taken to look under any flaps of tissue (30). Debridement of the scalp is [illegible]ally not a high priority as the excellent [illegible]larity will ensure the survival of even [illegible] contused tissue (30). The scalp is not [illegible]tic in older children and excessive [illegible] may create tension in closure. Bleeding [illegible]sels usually respond to wound closure lowed by pressure. It is usually not necessary to tie off individual bleeders (30).

Scalp wounds are generally prepared in the same manner as other wounds, with the obvious obstacle of the hair. Scalp wounds can usually be closed without prior hair removal. However, this may cause technical difficulties in suture placement and removal (67). Although the clinician is warned regarding unnecessary hair removal due to an increased risk of infection, this recommendation is based on studies of preoperative patients (25). It is unlikely that a scalp wound would become infected solely due to hair removal. Clipping the hair rather than shaving is a reasonable suggestion for scalp wounds (25).

Closure of the galea is recommended. Two general methods have been proposed for this. Some authorities feel that the galea should be closed together with the other skin structures by taking one large bite of tissue (43). This is recommended to decrease the amount of foreign body (suture) within the wound (43). Others advocate separate closure of the galea with absorbable sutures (60, 62, 67).

Scalp wounds often are amenable to repair by continuous skin sutures or staples. Suture size is usually 4.0 or larger and the highly visible blue coloring of Prolene® may offer advantages at the time of removal.

Forehead

The forehead is one of the easiest areas to predict the tension on the wound, as the RSTL run transversely. Lacerations that are vertically oriented will tend to heal with a wide scar (30). Lacerations angled greater than 35° from the RSTL will have a poor result (14). For anatomical reasons a vertical laceration situated in the midline is less likely to be problematic (30). Curved flap lacerations in this region may heal poorly due to the trap door effect caused by central contraction of the scar (43, 47). When the clinician is confronted with a large, unfavorably situated forehead wound, he or she should consider referral or warn the parents about the potential need for revision.

Forehead lacerations are common in children, and relatively few are referred to a plastic surgeon. However, the factor of skin tension must be appreciated even in small lacerations. The small vertical forehead laceration will be under tension and is therefore not suitable for primary closure by skin tapes. Efforts to counteract skin tension, including undermining and deep suture placement, should be considered. Using skin tapes to augment the repair initially and then for another 5 to 7 days after suture removal is recommended. Many people have small but unsightly forehead scars acquired as a result of an ED repair during youth. Extra care in the initial management and follow-up of these wounds will decrease the likelihood of such a result. Horizontally positioned lacerations, in contrast, heal well with skin tapes.

Windshield injuries unfortunately are common and typically present with multiple lacerations, abrasions, and some areas of tissue loss. Each individual laceration must be explored for the presence of glass (30). Multiple small wounds can be handled by a combination of loose single stitches, taping, or minor wound excision (30, 47). Subsequent dermabrasion or dermoplaning may be necessary for such injuries (47).

Eyebrows

Two essential points to remember in approaching lacerations of the eyebrow are that shaving the area must be avoided and that all excisional cuts must be angled parallel to the direction of hair follicle growth (30, 41, 47, 48). Regrowth of eyebrow hair is unpredictable; correct alignment of the eyebrow after it is shaved is difficult if not impossible; and perpendicularly placed excision cuts will damage an excessive number of hair follicles, leaving a wide hairless area. Debridement of the eyebrow, as with other facial structures, should be conservative (14, 30). Because the eyebrow is a major cosmetic landmark, approximation of this structure must be exact (47).

Eyelids

Simple lacerations of the eyelid are easily repaired but the following are indications for consultation with an ophthalmologist (30, 43, 68):

1. The presence of yellow fat indicates possible penetration of the orbital septum.
2. Lacerations of the free margin of the eyelids require meticulous repair to avoid subsequent deformity and disability.

3. The patient with a deep upper lid laceration should be evaluated for ptosis which indicates the need for repair of the levator palpebrae muscle.
4. Lacerations medial to the punctum on the lower lid can damage the lacrimal duct. The duct must be probed through the punctum with fine suture material and the wound examined for visualization of the suture indicating duct injury.
5. Medial eyelid injuries can disrupt the canthal ligament which will require special repair.

Nose

The superior aspect of the nose can be handled similar to other facial tissue whereas the inferior portion, due to the tight nature of the skin, is not amenable to significant excision (30). Fractures commonly accompany these lacerations; however, primary repair of the laceration may be undertaken in consultation with an otorhinolaryngologist. The presence of an underlying fracture will generally require the addition of antibiotic coverage. Facial blocks are useful when dealing with nasal lacerations. The free rim of the nose (around the nares) is an important cosmetic landmark and must be carefully closed.

Complete lacerations are closed in layers using absorbable sutures on the mucosal side (30, 68). The skin of the distal nose does not hold stitches well and the site is prone to forming stitch marks and abscesses. For this reason some authorities recommend a subcuticular suture for this area (43, 68). Alternatively, fine sutures can be used with early removal and subsequent skin taping. Skin taping, however, is difficult with adolescents, as the skin of the nose is quite oily (43).

Ears

Closure of ear wounds not involving the cartilage proceeds as with other wounds. If the cartilage has been violated it must be covered in some manner early in the care of the patient (30, 31, 43, 68). Small widths can be removed if needed for closure. If a large amount is exposed, early consultation should be sought for possible removal and preservation in a subcutaneous pocket.

If possible, the wound should be closed without suturing the cartilage to lessen the risk of infection (31). This is generally possible when the cartilage laceration is small and the cartilage edges are well apposed before suturing. If the cartilage is to be sutured, the perichondrium must be included as the cartilage will not hold a stitch. The posterior ear skin may be closed with absorbable sutures if the ear would need to be excessively bent to remove these sutures.

A conforming dressing should be applied by using moistened cotton balls to fill in the ear concavities and the space behind the ear (Chapter 58). A large compression wrap is then applied around the head. This is left in place for 2 days, and the wound is then examined for a subperichondrial hematoma which would require aspiration.

Lip

As described fully in Chapter 69, principles of lip closure are few and include conservative debridement with no debridement of the philtrum, a layered closure, and exact approximation of the vermillion border (30, 31, 43, 47, 68).

Tongue and Intraoral Lacerations

Fortunately most lacerations of the tongue in children will heal well without sutures. Those that are deep or involve a division of the [illegible] edge will need to be closed to avoid subsequent disability, prolonged healing, and late entrapment of food (43, 68). Other intraoral lacerations must be evaluated to ensure that no injury to the salivary ducts or facial nerve has occurred. Repair of these mucosal injuries is necessary only for deep lacerations to accelerate healing and to avoid complications (see Chapter 69).

Other Facial Areas

Evaluation of injuries to underlying structures, particularly the parotid duct and [illegible] nerve, is essential for lacerations involving the lateral aspects of the face. Due to the underlying bony prominence, the cheek [illegible] prone to a particular type of injury. The patient presents with a small laceration secondary to a blunt mechanism that may [illegible] significant muscle violation beneath the [illegible] face. If this is not recognized and repaired, [illegible] unsightly depressed scar may result (47) [illegible]pation of a soft tissue defect under the [illegible] ceration may be a clue to this injury. Extension of the skin wound is necessary to effect this type of repair and may be necessary to allow adequate visualization to determine if such complex repair is needed.

The chin is a common area for lacerations in children and the mechanism is virtually always blunt trauma from a fall. These wounds are tempting to debride but this is usually not necessary (30). If the wound is not under tension, as appreciated by visualizing the wound at rest, wound tapes can be used on the chin.

Extremity Lacerations

It is generally best to avoid deep sutures when possible in extremity lacerations where the baseline incidence of wound infection is higher (31). The high rate of infection of wounds in the lower extremities calls for careful evaluation of the need for any sutures at all in these wounds (19, 20, 29). This may be particularly pertinent to lacerations of the foot (11).

Lacerations over joints, especially the knee, will require prolonged immobilization of that joint if sutures are placed. Sutures may be foregone in some minor wounds in these areas rather than putting the patient through the inconvenience and expense of joint immobilization.

Lacerations through the tip of the finger are common in young children and are often caused by a closing door. These injuries can appear dramatic but usually heal well. Significant bony involvement should prompt consultation with an orthopedic surgeon, but most of these injuries can be handled by the emergency physician. Recommendations for handling these injuries are found in Chapter 106.

Continued Wound Care

Using antibiotics in the management of simple wounds is often an area of distinct disparity between the results of research and what is actually practiced. For routine lacerations, using antibiotics does not appreciably lower infection rates. In fact, some evidence indicates the opposite effect (71). Regarding hand lacerations, several studies indicate no benefit to using antibiotics (28, 72, 73). Some authorities suggest antibiotics for wounds when the predicted infection rate will be greater than 10% (1). This strategy, however, has not been proven in a clinical trial and the rate of infection in routine pediatric lacerations is well below this threshold (19, 20).

Human bite wounds of the hand are associated with a higher risk of infection, particularly for the closed fist injury (32). It is recommended that all such hand wounds receive antibiotics (32). Penicillin is a reasonable choice in noninfected wounds as it covers oral flora adequately. If a wound becomes infected, staphylococcal coverage must be added with continuation of the penicillin to cover *Eikenella corrodens*, a common organism in human bite wound infections (32). Bites in areas other than the hands generally heal well if they can be adequately cleansed and do not routinely require antibiotics. Facial dog bites, subject to excellent wound care, rarely become infected (40). Although many physicians feel the need to prescribe antibiotics for such wounds, little scientific basis for this practice exists.

Intraoral and perioral lacerations are considered to be contaminated wounds due to the high bacterial count of saliva (11, 68). Using antibiotics in such injuries is unproven and is an area of controversy (31, 48). If a clinician chooses to use an antibiotic, penicillin is adequate (68).

The need for a dressing on the sutured wound is quite limited. The purposes of wound dressings are to absorb secretions, to protect the wound surface, and to prevent infection from an external source (74). Most minor wounds do not ooze excessively and the wound edge is sealed to the outside within several hours (46, 74, 75). Clinical studies do not demonstrate an increased rate of infection in wounds that are not dressed (74).

Similar logic applies to the safety of early gentle cleansing with mild soap and water (75, 76). It is generally recommended to wait 8 to 24 hours before undressing or cleansing the wound. Wounds in certain areas such as the scalp are only dressed if a compression wrap is desired. If a dressing is applied to an extremity it is important to ensure that no pressure is applied proximal to the wound, risking edema (11).

Wound edges should be kept moist and free of scab in cosmetic areas (11). If scab is allowed to become interposed in the wound edges it will be replaced by scar tissue (11). Using both half-strength hydrogen peroxide and lubricating ointments within 6 hours of wound repair is recommended (11). Antibiotic ointments are commonly used for prophylactic purposes on wounds when in fact their main benefit is lubricating the edge rather than preventing infection (75).

Local heat application increases the perfusion to wounds and has a role in the prevention or management of wound infection (77). Other measures to consider include wound elevation and immobilization through bulky dressings or loosely fitted splints. A common oversight is failure to elevate hand injuries with the use of a simple sling. Likewise, prescribing crutches for lower extremity and foot lacerations often encourages the

SUMMARY

Wound Preparation

1. Provide conscious sedation as needed
2. Anesthetize wound
3. Provide hemostasis
4. Explore wound for foreign bodies or injuries to underlying structures
5. Remove contaminated or devitalized tissue through debridement and excision
6. Thoroughly cleanse wound
7. Undermine wound edges when necessary to reduce tension

Using Needle Holder

1. Grasp needle away from swage and closer to tip for tougher tissue
2. Hold needle perpendicular to needle holder
3. Enter skin perpendicular to surface
4. Stabilize or manipulate skin edges with skin hook or nontraumatic forceps
5. Retrieve needle after each pass with needle holder or forceps

Instrument Tie

1. Pull suture through wound, leaving a few centimeters at insertion site
2. Grasp longer (needle) length of suture in dominant hand
3. Loop suture twice *over* tip of needle holder
4. Grasp free end of suture with needle holder
5. Pull shorter (free) end through loops and away from side of wound initially entered
6. Tighten knot so that skin edges just come together
7. Loop needle end of suture once *under* tip of needle holder
8. Grasp free end of suture with needle holder
9. Pull free end through loop and back to initial needle entry side of wound

SUMMARY (CONTINUED)

10. Repeat single loop tie, first in over and then in under manner, for a total of four throws
11. Cut both ends of suture allowing adequate length to retrieve suture at time of removal

Simple Interrupted Skin Sutures

1. Enter skin with needle directed downward or angled sightly away from wound edge
2. Drive needle to a depth greater than its width
3. Trace a symmetric path through both sides of wound
4. Secure suture with an instrument tie

Inverted Subcutaneous Sutures

1. Insert needle from within wound at fat-dermal junction
2. Rotate needle up through tissue and exit in dermis
3. Insert needle in opposing dermis at an equal vertical and horizontal level
4. Rotate needle down through tissue and exit at fat-dermal junction
5. Bring both ends of suture to same side of loop
6. Secure suture with a knot consisting of three throws

Interrupted Mattress Sutures

Vertical Mattress

1. Place a wide, deep stitch across wound—use two steps (retrieving needle from within wound) when necessary
2. Reverse directions from previous stitch, entering same side as recent exit but at a point closer to wound edge and in line with previous pass
3. Complete a smaller and shallower pass on same side as initial entry site and equidistant from wound edge as second entry site
4. Tie knot on side of wound that was initially entered

Horizontal Mattress

1. Place an initial stitch of same dimension as a simple interrupted suture pass
2. Reenter skin lateral to exit point and equidistant from wound edge
3. Perform a second pass reversing directions from previous stitch and exiting at a point lateral to initial entry site and equidistant from wound edge, so that free and needle ends of suture remain on same side of wound
4. Tie knot on side of wound that was initially entered

Half-Buried Mattress or Corner Stitch

1. Enter skin below and just lateral to point of V
2. Exit within wound
3. Evert tip of flap with skin hooks or forceps

SUMMARY (CONTINUED)

4. Pass needle through dermis of flap tip, parallel to skin surface
5. Enter wound on opposite side of point of V
6. Exit through skin at a point below and lateral to point of V, symmetrically across from initial insertion site
7. Secure suture with an instrument tie

Continuous Skin Sutures

Simple Running Stitch

1. Place a simple interrupted suture at one end of laceration without cutting needle end of suture
2. Travel length of laceration performing sequential passes perpendicular to laceration and equidistant from each other
3. Maintain tension on needle end of suture following each pass
4. Reverse direction of needle pass once end of laceration is reached
5. Enter skin close to previous exit site, and leave a narrow loop on that side by only partially pulling suture through
6. Secure end of suture with an instrument tie using narrow loop as free end of suture

Running Subcuticular Stitch

1. Pass suture through skin at one end of wound and exit in dermis
2. Travel length of wound making small passes (less than 1 cm in width) within dermis and parallel to skin surface
3. Alternate sides of wound with each entry site slightly behind previous exit point and at same vertical level of dermis
4. Complete suture by bringing needle out through skin surface at end of wound
5. Cut needle from suture
6. Tape free ends of suture to skin surface using skin adhesive

Wound Tapes

1. Clean and dry skin surrounding laceration
2. Apply adhesive to surrounding skin
3. Place tape strips perpendicularly across wound leaving some space for oozing
4. Place extra tape strips across ends of previous strips and parallel to wound

Delayed Primary Closure

1. Anesthetize wound
2. Explore wound
3. Debride and excise wound as needed
4. Thoroughly cleanse wound
5. Fill wound cavity with sterile, fine mesh gauze
6. Cover wound with a bulky dressing
7. Remove dressing in 4 to 5 days and approximate edges with sutures or skin tapes if no infection or devitalized tissue is evident

patient to remain in the erect position. Crutches should be accompanied by admonitions to limit their use to essential travel for meals and bodily functions.

Sutures should be removed early and replaced with tapes if wound edema creates significant tension on them (46, 48). Increased pull on the sutures will lead to earlier formation of stitch marks. Stitch marks occur because of epithelialization of the suture tracks and can be avoided by removing sutures within 7 days (25, 46). The general schedule for suture removal is 3 to 5 days for the face, 7 days for scalp and anterior trunk lacerations, and 10 to 14 days for the extremities and back (30, 31, 43, 44).

COMPLICATIONS

Any disruption of the skin involving the dermis will heal by the formation of scar tissue. A primary goal in suturing lacerations should be to minimize the size and visibility of the scar. Formation of keloids and hypertrophic scars are the unavoidable result of an abnormal healing process; however, a poorly or incorrectly performed step in suture closure will increase the likelihood of producing an unsightly scar.

An uneven skin surface resulting from an elevation or depression of scar tissue will cast a shadow across the skin making the defect more obvious. This may result from a failure to adequately align the skin layers or from inverting rather than everting the epithelial layer during the closure. Formation of a hematoma in the subcutaneous layers can result in a depression in the skin surface once the hematoma has been absorbed. This may be avoided through closure of all skin layers.

Failure to accurately align natural landmarks such as the eyebrow or the vermilion border of the lip will be noticeable no matter how invisible the actual scar.

So-called dog ears result from excess tissue on one edge of the wound which is gathered at the end of the laceration. This may be a consequence of inaccurate alignment of wound edges by the clinician or the inevitable result of a laceration with avulsed tissue leaving unequal lengths of opposing wound edges. The clinician can avoid malalignment by sewing inward from both ends or by

CLINICAL TIPS

1. Adequate immobilization, sedation, and anesthesia are key to successful laceration repair in children.
2. Natural landmarks should be used. Shaving eyebrows and using epinephrine in anesthetizing the vermilion border obscures two important landmarks
3. Shaving the hair is generally unnecessary in the repair of scalp wounds.
4. The intrinsic and extrinsic tension forces across a laceration must be considered when planning the repair.
5. Delayed closure of wounds should be decided based on the location and the degree of contamination of the wound.
6. Only skin hooks, nontraumatic forceps, or fingers, should be used in handling wound edges.
7. The fewest number of sutures should be used for the shortest time period that is sufficient.
8. Three layers support sutures best: the fascial-fat junction, the dermal-fat junction, and the level just below the dermal-epithelial junction. Fat and muscle will not hold a stitch.
9. Wounds under greater tension should have more skin sutures placed and these should be closer to the wound edge.

Clinical Tips (Continued)

10. Wound edges should be approximated to accommodate edema which occurs after closure. Strangulation of tissue must be avoided.
11. Wound edges should always be everted, not inverted.
12. A pass that is wider at the base than the surface ensures eversion of the edges.
13. The use of colored sutures in hair improves visibility for eventual removal.
14. Suture ends should be cut long enough to allow easy handling for removal.
15. Parents should be told that the healing process and scar appearance will not be complete until 6 months after the repair.
16. Leaving sutures in place for prolonged periods of time or under excessive tension results in stitch marks.
17. Skin tapes can provide useful reinforcement to sutures, or continued support following suture removal.
18. The general schedule for suture removal is 3 to 5 days for the face, 7 days for the scalp and anterior trunk lacerations, and 10 to 14 days for the extremities and back.

throwing an initial suture in the center of a long laceration dividing it into two smaller, more manageable lacerations. Additional corrective methods are possible in instances when the formation of a dog ear is unavoidable.

Optimal healing depends on the transport of oxygen and nutrients to the site of injury. Excessive undermining or rough handling of tissue can disrupt this process, resulting in the death of tissue and increased scar formation.

Sutures also can produce scars. Excessive tension placed on the sutures will result in strangulation and ischemia of the tissue. Sutures may actually tear through the wound margin. Healing will occur by formation of more scar tissue rather than the natural regeneration of the epithelium. Sutures that are left in place for excessive periods also will leave permanent stitch marks. Knots of subcutaneous sutures will increase tissue reaction at the skin surface and may even break through the surface if not buried.

Functional impairment can result from undue tension imposed by sutures placed across a laceration that occurs in a location requiring a significant degree of mobility, such as a joint. Contractures occur when inadequate tissue is available to allow full mobility following healing. They also can occur as a result of the abnormal continuation of the normal process of wound contraction. Contractures occasionally can be averted through using splints that allow the laceration to heal in the position of greatest extension. In certain instances it may be preferable to allow the wound to heal by secondary intention.

Summary

Because lacerations occur commonly in children, laceration repair is a necessary skill for the clinician treating acute injuries in this patient population. Additional expertise is sometimes necessary, but the majority of wound closures do not require a subspecialist. Careful attention to the location and mechanism of the laceration, and an assessment of the risk of infection will help the clinician determine the best type of stitch, the size and type of suture material, and the need for prophylactic antibiotics. The clinician should possess a thorough knowledge of the properties of the skin and the orientation of relaxed skin tension lines. Exploration of the wound, proper cleansing and preparation, and appropriate follow-up wound care are also essential in optimizing function and minimizing scar formation. The best results are obtained when adequate mobilization, sedation, and analgesia are used.

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Management of lacerations in the emergency department

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Lacerations are one of the most commonly encountered problems in the emergency department (ED). In 1996, approximately 11 million wounds were treated in EDs throughout the United States [1]. Lacerations occur predominantly in young adults, primarily men [2].

Most wounds are located on the head or neck (50%) or the upper extremity (usually involving the fingers or hands; 35%) [3]. The most common mechanism of injury is the application of a blunt force, such as bumping one's head against a hard object (eg, table). This type of contact crushes the skin against an underlying bone causing it to split. Other causes of lacerations include sharp instruments, glass, and wooden objects [4]. Mammalian bites can also be a mechanism of injury; however, they are a relatively rare cause of injury [3]. Most patients present to the ED within several hours of injury and most have already attempted to cleanse or care for their lacerations [2].

Evaluation of the patient

Medical history

Proper wound management begins with a thorough patient history. Particular emphasis should be placed on the following host factors that can have adverse effects on wound healing [5,6]:

1. Extremes of age
2. Diabetes mellitus
3. Chronic renal failure

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4. Obesity
5. Malnutrition
6. Use of immunosuppressive medication (eg, steroids and chemotherapeutic agents)
7. Connective tissue disorders (eg, Ehlers-Danlos syndrome, Marfan syndrome)

A history of the mechanism of injury is essential in identifying the presence of potential wound contaminants and foreign bodies, which can result in chronic infection and delayed healing. The type of forces applied at the time of injury can also help predict the likelihood of infection. For example, crush injuries, which tend to cause greater devitalization of tissue, are more prone to infection than wounds resulting from the more common shearing forces [4]. Because anesthetic agents and antibiotics may be required, a detailed history of any allergies to these agents is essential. Tetanus immunization status should be verified. With the increased incidence of severe reactions to latex products, it is also useful to inquire about any prior allergic reactions to latex.

Physical examination

Wound examination should always be conducted under optimal lighting conditions with minimal bleeding. Examination under suboptimal lighting conditions or when the wound is obscured by blood impedes recognition of embedded foreign bodies and may result in unintentional damage to important structures, such as tendons, nerves, or arteries. To minimize the possibility of missing an injury to a vital structure, all wound examinations should begin with a neurovascular assessment of pulses, motor function, and sensation distal to the laceration.

Treatment and consultations

Most lacerations can be repaired in the ED. Few patients with lacerations require admission to the hospital. Most patients requiring surgical intervention can often be discharged with appropriate follow-up arrangements. The appropriate surgical specialist should be consulted for the following: open fractures of long bones; nerve or vascular injuries; flexor tendon disruptions; joint capsule disruptions; repair of specialized structures, such as the parotid or lacrimal duct; replacement of skin loss by a flap or graft; or extensive debridement. Complicated lacerations involving open fractures, flexor tendon injuries, nerve injuries, or arterial injuries are treated in the operating room. Often, definitive repair can be accomplished via same-day surgery. If the initial receiving hospital does not have the appropriate emergency or surgical specialist, transfer may be necessary.

Wound preparation and evaluation

Anesthesia

Most lacerations require some form of anesthesia for adequate evaluation and management. The most common form of anesthesia for lacerations is via local infiltration, which is painful, but reliable.

Minimizing pain of infiltration

To reduce the pain associated with local infiltration, several strategies may be used. Buffering of the local anesthetic with sodium bicarbonate results in more rapid diffusion of the anesthetic agent into nerve endings [7]. This reduces the pain associated with local infiltration without altering the ability of host defenses to prevent infection [7,8]. The use of warm anesthetic solutions, small needles, slow rates of infiltration, injection through the wound edges in noncontaminated wounds, and pretreatment with topical anesthetics are additional strategies that can be used to decrease the pain of infiltration [3,9–16].

Allergies to local anesthetics

Many patients report a past allergic reaction to a local anesthetic. Most often, an anesthetic from another class (amide or ester) can be substituted (Box 1).

These patients are often really allergic to methylparaben, the preservative used in the lidocaine multidose vials. Therefore, one option is to use single-dose lidocaine (cardiac lidocaine), which does not contain a preservative. Another alternative is to use an anesthetic agent unrelated to the "caines,"

Box 1. Classes of local anesthetics

Amides

Lidocaine
Bupivicaine
Etidocaine
Mepivicaine

Esters

Procaine
Cocaine
Tetracaine
Benzocaine
Chloroprocaine

such as diphenhydramine or benzyl alcohol [17,18]. When using diphenhydramine as a local anesthetic, it is important to dilute the solution to 1% to avoid the risk of tissue necrosis. Although an effective local anesthetic, local infiltration of diphenhydramine is more painful than with the "caines" [18,19]. Benzyl alcohol (a preservative in normal saline vials) has been shown to be as effective as lidocaine, yet much less painful to inject than diphenhydramine [20]. When a solution of 0.9% benzyl alcohol with epinephrine is used, the duration of action is longer than that of diphenhydramine [17].

Topical and regional anesthesia

Alternative methods of local anesthetic administration include topical and regional application. Several topical anesthetics used for wound anesthesia are as follows: a combination of tetracaine, adrenaline, and cocaine (or TAC); a combination of lidocaine, epinephrine, and tetracaine (or LET); and a eutectic mixture of local anesthetics, or EMLA (AstraZeneca, Westborough, MA) cream [19,21–29]. Application of topical anesthetics prior to needle infiltration may reduce the pain of infiltration. Use of topical anesthetics alone may be considered for small superficial lacerations.

Regional anesthesia is a valuable alternative to local anesthesia. It offers the benefit of providing anesthesia to a relatively large area of skin with minimal doses of anesthetics. Methods used to reduce the pain of regional anesthesia include buffering and intraoral versus transcutaneous administration where appropriate [30,31]. Full discussion of methods of regional anesthesia can be found in most emergency medicine textbooks.

Hemostasis

External bleeding can almost always be controlled with direct pressure. When lacerations continue to bleed despite reasonable direct pressure, a sphygmomanometer can be placed proximal to the injury and inflated to a pressure greater than the patient's systolic blood pressure. This technique helps control bleeding to allow for proper examination. Vasoconstrictors, such as epinephrine, can be used as adjuncts to the local anesthetic agents. They reduce bleeding and oozing within the laceration, allowing for easier exploration and wound closure. The use of vasoconstrictors has not been found to increase the infection rates of wounds. Vasoconstriction is discouraged in areas with end organ blood supply, such as the fingers, nose, penis, and toes.

Wound cleansing

Mechanical forces are commonly used to cleanse the wound of bacteria and other particulate matter that may be retained on the wound surface by adhesive forces. For these forces to be successful, they must exceed the adhesive forces of the contaminant. The most common mechanical force used is that of irrigation (hydraulic forces). There is some debate over the optimal method of irrigation and the preferred solution. The efficacy of wound irrigation can be correlated with the pressure at which the irrigant is delivered to the wound [32,33].

During irrigation, the hydraulic forces of the irrigating stream act on particulate matter in the wound. The magnitude of the hydraulic force is a function of the relative velocities and the configuration of the particle. When subjected to the same irrigating stream, particles with a smaller surface area experience more force than particles with a larger surface area. Thus, it takes significantly less hydraulic pressure to rid the wound of large foreign bodies than it does to remove bacteria.

In an experimental contaminated wound model, high-pressure irrigation was more effective than low-pressure irrigation in reducing bacterial wound counts and wound infection rates [34]. High-pressure irrigation successfully cleans wounds of small particulate matter, such as bacteria and soil. This type of cleansing reduces the infection rate of experimentally contaminated wounds. In contrast, low-pressure irrigation, even with large volumes of fluid, has negligible capability for removing small particles (bacteria and soil), but removes large particulate matter, such as devitalized tissue.

Despite the lack of clinical studies, most authorities recommend irrigation impact pressures in the range of 5 to 8 psi [32]. Wound impact pressures in the range of 5 to 8 psi can be easily obtained using a 30- to 60-mL syringe and a 19-gauge needle [34] or Zerowet splash shield (Zerowet, Inc., Palos Verde, CA). Sustained high-pressure irrigation can result in tissue damage. At very high irrigation pressures, therefore, infection rates actually increase [32,35]. Thus, for individual wounds, the benefits of high-pressure irrigation should be weighed against the potential risks for wound infection. For example, high pressures should be avoided in noncontaminated wounds located in highly vascularized areas containing loose areolar tissue (eg, the eyelid). Increased edema may prevent an optimal cosmetic closure. Conversely, high-pressure irrigation is clearly indicated for contaminated wounds of the lower extremity.

The choice of irrigation solution is relatively straightforward. Normal saline is the most cost effective and readily available choice. It has compared favorably with more expensive, less easily available alternatives [36]. Because of their tissue toxicity, detergents, hydrogen peroxide, and concentrated forms of povidine iodine should not be used to irrigate wounds [32,37,38]. Irrigation volume should be individualized based on patient and wound characteristics, such as location and cause of wound.

Wound closure

After wound cleansing, the physical integrity and function of the injured tissue must be restored. Most lacerations require primary closure. Primary

closure results in faster healing and reduced patient discomfort when compared with secondary closure. Whereas several methods for closing lacerations exist, the most commonly used method remains suturing [2]. Most wounds should be closed primarily to reduce patient discomfort and speed healing.

Timing of closure

Although there is a direct relationship between the time interval from injury to wound closure and the risk of subsequent infection, the length of this "golden period" is highly variable [39–42]. A study of hand and forearm lacerations found that closure within 4 hours had a lower infection rate than later closure [43]. A study of pediatric patients, however, did not find a difference in infection rate for lacerations closed within or more than 6 hours from the time of injury [39]. A widely quoted study from Jamaica found that facial lacerations healed well regardless of the time to closure. In contrast, trunk and extremity lacerations had lower rates of healing if they were closed more than 19 hours from the time of injury, compared with earlier closure [40].

Based on these studies, it seems most appropriate to consider each individual laceration separately, taking the time from injury to presentation into account, along with location, contamination, risk of infection, and importance of cosmetic appearance before deciding whether to perform primary wound closure. Wounds that are not closed primarily because of a high risk of infection should be considered for delayed primary closure after 3 to 5 days when the risk of infection decreases.

The ideal wound closure technique should allow a meticulous wound closure, be rapid and easy, be painless, be inexpensive, result in minimal scarring with a low infection rate, and be of low risk to the health care provider. Sutures are the most commonly employed wound closure technique. Other alternatives include staples, surgical tapes, and more recently, tissue adhesives.

Sutures

Sutures are the standard method used to obtain a meticulous wound closure with the greatest tensile strength and lowest likelihood of dehiscence. The most complex laceration can be well approximated with sutures. The choice of suture technique should be determined by the configuration and biomechanical properties of the wound, in combination with an assessment of the risk of infection. Percutaneous sutures pass through the epidermal and dermal layers of the skin. They are used alone for low-tension lacerations and in combination with dermal sutures for higher-tension lacerations. Percutaneous sutures are performed with nonabsorbable suture thread, such as nylon or polypropylene. Nonabsorbable sutures retain most of their tensile strength for more than 60 days and are relatively nonreactive [1,44–46]. Removal of nonabsorbable sutures is required. Nonabsorbable sutures made from natural fibers potentiate infection more than synthetic sutures, from the reaction of tissue to these sutures in clean wounds. Sutures containing silk or cotton should be avoided in wounds that have significant bacterial contamination. The incidence of infection in contaminated wounds containing monofilament sutures is lower than in those containing multifilament sutures.

Dermal sutures reapproximate the divided edges of the dermis without penetrating the epidermis. Percutaneous and dermal sutures are often used together. Dermal closures are generally performed with absorbable sutures. Most increase the duration of time the wound retains 50% of its tensile strength, from 1 week to as many as 4 weeks. Synthetic absorbable sutures are less reactive and have greater tensile strength than sutures from natural sources such as catgut. Some synthetic absorbable sutures retain their tensile strength for as long as 2 months, making them useful in areas with high dynamic and static tensions. Deep sutures help relieve skin tension and decrease dead space and hematoma formation. Animal studies have found that dermal sutures increase the risk of infection in highly contaminated wounds [47–49]. They do not, however, increase the risk of infection in clean, noncontaminated lacerations [47,49]. Sutures placed through adipose tissue do not reduce tension and they increase the infection rate [50]. Thus, deep sutures should not be placed in adipose tissue and should be avoided, when possible, in contaminated wounds. Synthetic and monofilament sutures have decreased rates of infection compared with natural and braided sutures [42,51–53].

Staples

Staples can be applied more rapidly than sutures [53,54]. Staples are associated with a decreased rate of foreign body reaction and a lower infection rate. [51–53]. In general, staples are considered particularly useful for scalp, trunk, and extremity wounds [44]. They are also useful in situations where time is limited, such as with multiple traumas or mass casualties [44]. Staples do not allow as meticulous a closure as sutures, however, and are slightly more painful to remove [44,53–55]. The timing of staple removal is similar to that of sutures. Removal of staples requires a staple removal device, which may not be available in all primary care provider offices.

Skin closure tapes

Surgical tapes are even less reactive than staples [52,54,56]; however, they require the use of adhesive adjuncts, such as tincture of benzoin, which increase local induration and wound infection [57]. Most adhesive adjuncts

are toxic to wounds. When applying them to the wound area, care should be taken to prevent them from entering the wound. Although the various surgical tapes have different degrees of adhesion, porosity, breaking strength, and elasticity [56], tapes alone cannot maintain wound integrity in areas subject to tension [44,58]. Adhesive tapes have the lowest tensile strength of wound closure devices. Because of their high rates of dehiscence, the inability to use them in hair-bearing areas, and the inability of patients to get them wet, surgical tapes are seldom used for primary wound closure in the ED [44]. Their use is limited to linear lacerations under minimal tension and after suture removal to decrease tension on the wound until they fall off.

Tissue adhesives

Tissue adhesives (eg, Dermabond, Ethicon, Inc., Somerville, NJ) were approved for use in the United States in August 1998. Tissue adhesives are cyanoacrylate polymers. The 2-octylcyano-acrylates are more stable, have greater flexibility, and maintain an even stronger bond than n-butyl-cyanoacrylates. They have a breaking strength three to four times greater than the butylcyanoacrylates, and degrade much more slowly. They are considered to be nontoxic [59–61].

Observational studies of children with small scalp, face, or limb lacerations treated with Histoacryl Blue, a butyl-2-cyanoacrylate, found low infection and dehiscence rates [59–61]. Histoacryl Blue results in long-term cosmetic outcomes similar to 5-0 and 6-0 sutures when used for repair of small facial lacerations [62,63]. Several clinical studies have compared the use of 2-octylcyanoacrylates with 5-0 and 6-0 sutures [64–66]. In all the studies, the 3-month cosmetic outcome, short-term rate of infection, and rate of wound dehiscence were similar. The time to wound closure was reduced by more than 50% in the group treated with the tissue adhesives [67]. Use of octylcyanoacrylates for skin closure following elective facial plastic surgical procedures produced better long-term results than sutures [68]. In vitro and in vivo studies have found that cyanoacrylate tissue adhesives have gram-positive antimicrobial properties [69,70]; however, it is imperative that clinicians adhere to standard wound preparation and wound cleansing procedures. When tissue adhesives are used without anesthesia, and without thorough wound cleansing, an increased rate of wound infections has been observed.

Application of tissue adhesives is rapid and relatively painless. Tissue adhesives do not require suture removal. They usually slough off in 5 to 10 days as the keratinized layer of epithelium sloughs. They should only be used topically. Tissue adhesives should not be placed within the wound or between wound margins. The 2-octyl-cyanoacrylate adhesives can be used in locations that could otherwise be closed with 5-0 or 6-0 nonabsorbable sutures. They can be used in higher-tension areas only if subcutaneous or subcuticular absorbable sutures are placed to relieve tension on the skin edges. They should not be used over areas of high tension or repetitive movement, such as over joints. When the tissue adhesive is painted on the laceration, three to four coats should be applied to provide adequate strength to the wound closure. Care should be taken to avoid applying too much tissue adhesive because polymerization is associated with an exothermic reaction. Increased rates and amounts of polymerization may be associated with increased heat sensation by the patient. For optimal results, cyanoacrylates should be applied to a bloodless field. When 2-octylcyanoacrylates are used, care should be taken to avoid picking, scrubbing, or soaking the area. If the tissue adhesives remain on the skin for a prolonged period of time, antibiotic ointment, white petroleum jelly, or bathing (soaking) will accelerate removal.

Wound care

Postoperative wound care should optimize healing. It must be tailored to the type of wound and the method of wound closure. Sutured or stapled lacerations should be covered with a protective nonadherent dressing for 24 to 48 hours until enough epithelization takes place to protect the wound from gross contamination [71]. Maintenance of a moist wound environment increases the rate of re-epithelization in sutured or stapled lacerations [72,73]. In addition, it has been suggested that topical antibiotic ointments may help reduce infection rates and prevent scab formation. Although white petrolatum may be as effective as bacitracin in the ambulatory surgery setting [74], topical antibiotics result in lower infection rates than white petrolatum in traumatic lacerations [75]. Patients whose lacerations are closed with tissue adhesives, however, should not have topical ointments applied to the wound. They loosen the tissue adhesive and may result in wound dehiscence.

Sutured or stapled lacerations should be kept clean and dry. Patients may gently cleanse the area after 24 to 48 hours. Patients with tissue adhesives may shower, but they should avoid bathing or swimming. Prolonged exposure to moisture loosens the tissue adhesive bond. Gentle blotting to dry the area is preferred. Repeated wiping may result in dehiscence. Elevation of the injured area decreases edema formation. Patients should observe the wound for erythema, warmth, swelling, and drainage because these may be signs of a developing wound infection.

Prophylactic antibiotics should not be prescribed. Several clinical studies and a meta-analysis have found that there is no benefit to prophylactic antibiotics for routine laceration repair [76–80]. Use of antibiotics should be individualized based on the degree of bacterial contamination, the presence of infection-potentiating factors, such as soil, the mechanism of injury, and the presence or absence of host predisposition to infection. In general, decontamination is far more important than antibiotics. Prophylactic antibiotics should be used in most human, dog, and cat bites, intraoral lacerations, open fractures, and exposed joints or tendons [44,81,82].

Sutures and staples over most areas of the body should be removed after approximately 7 days. Facial sutures should be removed sooner (within 3–5 days) to avoid formation of unsightly sinus tracts. Sutures subject to high tensions (eg, joints, hands) should be left in for 10 to 14 days (Table 1). When tissue adhesives are used, care should be taken to avoid picking or scrubbing of the area or exposure to water for more than brief periods of time. When tissue adhesive remains on the skin for prolonged periods, antibiotic ointment, white petroleum jelly, or bathing can be used to accelerate removal. Acetone can be used when more rapid removal is required.

Wounds can develop hyperpigmentation when exposed to the sun. All wounds should be protected with a sun-blocking agent for at least 6 to 12 months after injury. Every patient should be evaluated for tetanus immunization. Proper immunization plays the most important role in tetanus prophylaxis.

Special topics

Foreign bodies

Only a small percentage of lacerations and puncture wounds treated in the ED contain foreign bodies. Physicians must consider the possibility of a concealed foreign body in any wound that penetrates the dermis, however. Wound exploration for foreign bodies should be a routine part of laceration management. Some foreign bodies are incidental findings, but most are found during a deliberate and careful search in wounds considered to be at high risk.

History and physical examination

Information obtained from the history and physical examination can suggest the presence of foreign bodies [83–85]. The mechanism of injury and

Table 1
Optimal time for suture removal

Location	No. days
Face	3–5
Scalp	7
Chest	8–10
Back	10–14
Forearm	10–14
Fingers	8–10
Hand	8–10
Lower extremity	8–12
Foot	10–12

the shape of the wounding object can also help determine the type of foreign body, its depth, and the likelihood of multiple fragments. Bites, closed fist injuries, and intraoral lacerations may contain tooth fragments. Objects that shatter, splinter, or break when inflicting a wound often leave remnants behind. Wood splinters tend to fragment when they are pulled out of a puncture wound. Thin needles, thorns, and spines often penetrate soft tissue deeply before breaking off. If glass broke in the patient's hand, there is a higher risk of a glass foreign body than if previously broken glass lacerates skin. Puncture wounds are more likely to contain glass than are lacerations [86]. Nails that penetrate socks and shoes may drive leather, rubber, or cloth into the plantar surface of a patient's foot [87,88]. Patients are not usually aware of the presence of foreign bodies in their wounds. A report of a sensation of "something in the wound" should be taken seriously, however. Frequently, the patient's perception is correct [86,89]. Sharp, well-localized pain with palpation over a puncture wound is a useful sign.

All lacerations should be visually inspected for the presence of foreign bodies. Adequate lighting, good hemostasis, complete local anesthesia, and patient cooperation are essential for success. Because they are narrow and deep, puncture wounds are more difficult to examine. If there is concern that a puncture wound contains a foreign body, the wound margins can be extended with a scalpel. Probing of deep puncture wounds with a closed hemostat may produce a grating sensation if a hard object is contacted. Failure to feel foreign bodies with probing does not exclude their presence, however. Hemostats should not be used to grasp blindly for potential foreign bodies. This can result in damage to underlying structures. Direct visualization is the preferred method of exploration.

Imaging studies

Various imaging studies can be used to evaluate wounds when the history or physical examination suggest the presence of a retained foreign body and nothing is found during exploration or to evaluate a wound for remaining foreign bodies after multiple foreign bodies have been removed. In addition, imaging studies can be used to determine if a foreign object has fragmented during removal and to examine a wound that cannot be explored thoroughly by direct visualization.

Plain radiography is the most readily available, easiest to interpret, and least expensive imaging method, and it will detect most foreign bodies found in wounds. Metal, bone, teeth, pencil graphite, certain plastics, certain glass, gravel, sand, some fish bones, some wood, and some aluminum are visible on plain radiographs [90–94]. Most glass that is 2 mm or larger is visible on plain radiographs. More than half of glass fragments between 0.5 and 2.0 mm are seen on plain films [95]. Glass does not have to contain lead to be visible on plain radiographs [96]. Underpenetrated radiographs enhance the contrast between the foreign bodies and the surrounding tissue [93].

Computed tomography (CT) scanning can detect more types of foreign material than plain film radiography. CT is 100 times more sensitive in differentiating densities, particularly with a narrow window adjustment and with digital edge-enhancement techniques [97–99]. Some wood, thorns, and spines not visible on plain radiographs have been identified with CT [97,98,100], but not all types are visible [93].

Sonography has been used with varying degrees of success to diagnose soft tissue foreign bodies in experimental models. In some studies, wood, fish bones, sea urchin spines, and other vegetative material were accurately identified. In other studies, the false-positive rate for nonradiopaque foreign bodies was very high. In various studies, the overall sensitivity of ultrasonography was 50% to 90%, and the specificity was 70% to 97% for gravel, metal, cactus spines, wood, and plastic [92,94,101,102,186,188]. The accuracy of sonography depends on the size of the object and the skill of the operator.

The role of MRI for soft tissue foreign body detection has not been defined.

Treatment and removal of foreign bodies

Every effort should be made to identify the presence of a foreign body during the initial visit [103]. When a soft tissue foreign body is discovered in a wound, the physician must weigh the risk of leaving the foreign body in place against the potential harm of attempting to remove it. All accessible foreign material within new wounds should be irrigated away, debrided, or extracted with instruments. The decision to remove a deeply embedded foreign body depends on size, location, composition, accessibility, and anticipated mechanical and inflammatory effects of the object.

Small, inert, deeply embedded objects that cause no symptoms can usually be left in place. Bullets are usually not removed because the procedure can cause more damage than leaving the object in place. Projectiles may drag bits of clothing or skin into the wound, however, and this foreign material should be removed. Vegetative foreign bodies cause intense and excessive inflammation and should be removed immediately. Foreign bodies that are heavily contaminated should be removed as soon as possible. Glass, metal, and plastic are relatively inert, and removal can be postponed if necessary.

When reactive foreign bodies are left in a wound, the normal inflammatory response during wound healing may intensify, resulting in a delay in healing or a destruction of surrounding soft tissue and bone. Inert material may not elicit any response, whereas vegetative material provokes an intense inflammatory response. Objects with smooth, nonporous surfaces produce less inflammation and fibrosis than those with rough surfaces. If the body fails to dissolve or extrude the foreign material, it may encapsulate it within a cyst. Once the retained foreign body is encapsulated, the inflammatory reaction subsides [41,104–106].

The most common complication of a retained foreign body is infection. Foreign objects can also cause mechanical damage by compressing or lacerating anatomic structures, sometimes years after the initial injury [107–109]. Foreign bodies have been reported to cause vascular occlusion, erosion, and thrombus formation, and to migrate to distant sites [110].

Removal of foreign bodies requires good anesthesia (local or regional), optimal lighting, adequate hemostasis, patient cooperation, time, and sometimes, magnification and assistance. Removal techniques include extraction by splinter or alligator forceps, dissection and debridement, and block excision [111–115]. Further details on these techniques can be found in most emergency medicine textbooks.

The benefit of prophylactic antibiotics for retained foreign bodies has not been studied. Clinical experience suggests that wound infections associated with a retained foreign body are resistant to antibiotics. These wound infections often resolve spontaneously once the foreign bodies are removed [116–118]. Antibiotics are justified for infected wounds, however, particularly when foreign body removal must be postponed, and for penetration of bones, joints, and tendons.

Puncture wounds

The most common site for puncture wounds are the feet. There are many different ways to manage plantar puncture wounds. Some physicians prefer expectant therapy. Others prefer exploration for and removal of foreign bodies, with the subsequent use of prophylactic antibiotics in an attempt to prevent the development of a wound infection.

The complication rate from plantar puncture wounds is higher than the rate for puncture wounds elsewhere in the body (with exception of the hands). One reason is the small distance from the plantar skin surface to bones and joints of the feet. Another is the force with which puncture wounds are inflicted when the weight of the body pushes against a sharp object. Finally, penetration of a shoe and stocking by a nail (or other sharp object) can push foreign bodies into the deepest recesses of the wound. These foreign bodies are rarely seen on plain radiographs.

Infections of plantar wounds can often have serious consequences and lead to disability or amputations. Osteomyelitis and septic arthritis are the worst of the complications. *Staphylococcus aureus* and *Pseudomonas aeruginosa* are the most common isolates from plantar puncture wound infections [88]. *Pseudomonas* infections are associated with puncture wounds through tennis shoes [119,120]. Clostridial infections can also develop in deep, closed plantar puncture wounds.

Exploration of plantar puncture wounds for foreign bodies is technically difficult. The skin in this region is thick, relatively rigid, and quite sensitive. Foreign bodies that penetrate the plantar fascia are almost impossible to locate through a narrow puncture wound. Irrigation of deep puncture wounds is futile because the irrigant solution does not completely drain out of the wound.

There is much controversy over plantar puncture wound exploration for foreign bodies and probing as a sufficient method of exploration for foreign objects. One author reported a 3% rate of retained foreign bodies after initial surface cleansing without exploration [121]. Some recommend enlarging the puncture wound to allow for deeper irrigation and exploration [122], especially if bone or joint involvement is suspected [123]. Others believe that removing a block of tissue down to the subcutaneous layer allows adequate visualization of accessible foreign bodies and removal of most of the contaminated tissue [124]. And others simply trim jagged epidermal skin edges [125]. Simple probing and blind grasping have unknown false-negative rates [126] and may force foreign bodies deeper into the wound [115]. The percentage of unexpected foreign bodies that are discovered and removed during the initial visit is unknown. It is also not clear how many infections are averted because of probing, excising, or incising and exploring plantar puncture wounds. Although the healing of the wound may be delayed by the latter two approaches, infection will delay wound healing even more. Some authors recommend extending the length of new, uninfected wounds and exploring the wound by spreading the wound edges apart for plantar puncture wounds caused by thorns, spines, wood splinters, contaminated objects, or by nails that penetrated footwear. If debris is seen in the wound tract, a small amount of tissue should be excised. Sewing-needle plantar puncture wounds require plain radiographs and often do not require exploration. Glass plantar puncture wounds also require plain films. If a wound infection is present, the risk of foreign body is very high, and imaging or exploration is mandated.

Another controversy involves the use of prophylactic antibiotics for this type of injury. Many authors do not recommend the use of antibiotics for new plantar puncture wounds. They argue that antibiotics do not compensate for inadequate initial wound care, they are ineffective in wounds with retained foreign bodies, and they may contribute to a gram-negative infection; however, wound infections that do not have a retained foreign body respond quickly to initiation of antibiotics [119,120,126–128]. In the only study of antibiotics in plantar wound infections, the infection rate was lower in the antibiotic group [129].

Bites

Dog bites

There are an estimated 1 to 2 million animal bites treated each year in the United States. Not all bite victims seek medical attention, many because of the trivial nature of their wounds. The most frequent complication from bites is infection. Dog bites have an infection rate of 1.4% to 30% [58,91,130–141]; cat bites, 15.6% to 50% [142–145]; and human bites, 9% to 18% [146,147].

Dog bites account for 63% to 93% of reported animal bites in humans [148–151]. Dog bite victims are often male, and most are pediatric patients [152,153]. Pediatric dog bite victims acquire mostly head, neck, and upper extremity wounds. Adults have mostly upper and lower extremity injuries [154,155]. Dogs have large teeth, which result in crushing and tearing of tissue. Dog bite injuries comprise the following: lacerations (31%–45%), puncture wounds (13%–34%), and superficial abrasions (30%–43%) [156]. Primary wound closure is employed in 12% of patients [148].

Pasteurella species is the most common pathogen isolated from infected dog bite wounds (50%–53%) [148,157]. *Streptococcus* species is found in 29%, and *S aureus* is found in 20% to 29% of infected dog bite wounds. *Pasteurella multocida* is a small, nonmotile, gram-negative coccobacillus, which is of low virulence in humans. It acts as an opportunistic pathogen. Wound infections caused by this organism are characterized by a rapidly developing intense inflammatory response that occurs within 24 hours of sustaining the injury. Pain and edema are prominent. *Pasteurella* is most sensitive to penicillin G and its derivative, second- and third- generation cephalosporins, tetracyclines, chloramphenicol, fluoroquinolones (ciprofloxacin, ofloxacin, enoxacin, levofloxacin), trimethoprim-sulfamethoxazole (Bactrim), clarithromycin, and azithromycin [158–162].

The role of prophylactic antibiotics in dog bite wounds is controversial. A meta-analysis of eight randomized trials of antibiotics to prevent infection in patients with dog bite wounds showed that the relative risk for infection was 0.58 [81,143,150,151,185,187]. Patients with full-thickness (completely penetrating the dermis into the subcutaneous tissue layers) puncture, hand, or lower extremity wounds, and dog bites requiring surgical debridement should be considered at higher risk for infection and should be prescribed antibiotics. The patient can be placed on a 5-day regimen of amoxicillin/clavulanic acid (Table 2).

If clinical signs of infection develop within 24 hours of the injury, the pathogen is most likely *P multocida*. The patient can then be started on an outpatient regimen of amoxicillin/clavulanic acid. For penicillin-allergic patients without a history of anaphylaxis, cefuroxime or cefixime can be prescribed. In patients allergic to penicillin and cephalosporins, azithromycin or clarithromycin can be used.

Patients who develop clinical signs of wound infection after 24 hours of the injury are more likely to have infections from *Staphylococcus* and *Streptococcus* species. Low-risk patients with only local cellulitis can be closely followed as outpatients. Patients with deep structure involvement, lymphangitis, lymphadenitis, tenosynovitis, septic arthritis, or systemic signs (eg, fever, malaise) should be admitted for intravenous antibiotic therapy and surgical consultation. Inpatient antibiotic therapy for dog bite wound

Table 2
Antibiotics of choice for prophylactic or outpatient treatment of animal bite wounds

Bite	Primary choice	Alternative choice
Dog	Amoxicillin/clavulanic acid, 875/125 mg PO 2×d	Clindamycin + fluoroquinolone (adults) Clindamycin + TMP/SMX (children)
Cat	Amoxicillin/clavulanic acid, 875/125 mg PO 2×d	Cefuroxime axetil, 0.5 g 2×d or doxycycline, 100 mg PO 2×d
Human	Amoxicillin/clavulanic acid, 875/125 mg PO 2×d	Clindamycin + fluoroquinolone or TMP/SMX

Abbreviations: PO, orally; TMP/SMX, trimethoprim-sulfamethoxazole.

From Goldstein EJC, Citron DM. Comparative activities of cefuroxime, amoxacillin-clavulanic acid, ciprofloxacin, enoxacin, and ofloxacin against aerobic and anaerobic bacteria isolated from bite wounds. Antimicrob Agents Chemother 1988:32:1143–7; and Goldstein EJC, Citron DM, Gerardo SH, et al. Activities of HMR 3004 (RU 64004) and HMR 3647 (RU 66647) compared to those of erythromycin, azithromycin, clarithromycin, roxithromycin, and eight other antimicrobial agents against unusual aerobic and anaerobic human and animal bite pathogens isolated from skin and soft tissue infections in humans. Antimicrob Agents Chemother 1998;42:1127–32.

infections without sepsis includes pencillin G and nafcillin, pending wound culture results. This combination covers *Pasteurella*, *Streptococcus*, and *Staphylococcus* species. If sepsis is suspected, aerobic and anaerobic wound and blood cultures should be obtained. The patient can then be started on imipenem/cilastatin or ampicillin/sulbactam, pending culture results.

Cat bites

Cat bites account for 5% to 18% of all animal bites treated in EDs [142,143,150]. Cat bite injuries occur on the upper extremity and hands (67%), head and neck (15%–20%), lower extremity (10%–13%), and on the trunk (0%–5%) [132,145,163–168]. Cat bites are most often puncture wounds (57%–86%) or superficial abrasions (9%–25%). Lacerations are less common (5%–17%) [142,143]. The most common complication is a wound infection.

The bacteriology of cat bite wounds is less complex than other bites. The cat's oral and nasal secretions contain mostly *P multocida* (70%–90%) [169–171]. *P multocida* is therefore the major pathogen in cat bite wound infections [145,169,171,172]. It is isolated in 53% to 80% of cultured cat bite wound infections [144,145,157]. *S aureus* wound infections are much less common in cat bites than in dog bites [143].

Cat bite victims with full-thickness puncture wounds, hand or lower extremity wounds, and those who are older than 50 years should be prescribed antibiotics on initial presentation, which should consist of a 5-day course of oral antibiotics. In most cases, amoxicillin/clavulanate is the drug of choice (see Table 2). In patients allergic to both penicillin and cephalosporins, azithromycin or clarithromycin are used. In nonpregnant adults, tetracycline or a fluoroquinolone can be used. Patients who develop wound infections should be treated based on the time to onset of symptoms, as described previously for dog bites.

Human bites

Human bites are the third most common animal bite in the United States. The estimated annual incidence in unknown, however [173]. The hand is involved in 60% to 75% of cases [174]. There are two types of human bites: occlusional bites and closed fist injuries. Occlusional bites occur when the teeth are sunk into the skin, crushing the tissue and creating teeth marks, contusions, abrasions, lacerations, avulsions, or amputations. Closed fist injuries occur when the closed fist strikes the teeth of another person, most commonly during a fight. It occurs mostly in young men and involves the third or fourth metacarpophalangeal (MCP) joint of the dominant hand [173]. There is often a delay in seeking medical attention, resulting in a delay in diagnosis and a high incidence of complications [175]. The wound is frequently small (5 mm in length) and initially not considered serious to the patient. Within 6 to 8 hours, the hand may become painful and edematous, and a purulent exudate may be present. All small lacerations over the dorsal MCP joints should be considered human bites until proven otherwise.

All clenched fist injuries should undergo local meticulous exploration to rule out involvement of deeper structures. Because the injury occurs with the hand in the closed position, when exploring the wound the hand should be in the clenched fist position and should then be fully ranged to explore the full length of potential injury.

In children, human bites are usually from fighting (62%) or playing (26%). Most are superficial abrasions (75%) that do not develop wound infections when antibiotics are not prescribed [146]. One study reported a 50% incidence of infection after hand bites, including osteomyelitis (16%), septic arthritis (12%), and tenosynovitis (22%) [176].

The most common organisms cultured from human bite wound infections are *S aureus* and *Streptococcus* species [146,177]. Gram-negative infections do not usually occur by themselves [177,178]. They are usually associated with a gram-positive infection [177]. Anaerobic organisms are cultured from 42% of infected wounds; the most common are *Enterobacter*, *Proteus*, *Serratia*, and *Eikenella* organisms [175]. *Eikenella corrodens* is a gram-negative rod, which is a facultative anaerobe. It is the infecting organism in 7% to 29% of human bites. It is more common in closed fist injuries [179]. *Eikenella* is sensitive to penicillin G, ampicillin, carbenicillin, cefoxitin, fluoroquinolones, trimethoprim-sulfamethoxazole, and tetracycline [175,179]. It is resistant to oxacillin, methicillin, nafcillin, most aminoglycosides, and clindamycin. *E corrodens* is an important cause of chronic infection and should be suspected in patients treated with first-generation cephalosporins who do not respond to the antibiotics [173].

Prophylactic antibiotics are recommended for full-thickness wounds, particularly clenched fist injuries and wounds that contain devitalized tissue. The antibiotic regimen consists of a 5-day course of amoxicillin/clavulanic acid (see Table 2). Patients allergic to penicillins and cephalosporins can be given erythromycin, azithromycin, clarithromycin, fluoroquinolones, or clindamycin [173,180]. Infected wounds should be cultured, and empiric antibiotics should be started. These should cover for *S aureus*, *E corrodens*, *Haemophilus* species, and anaerobic bacteria [173]. Patients with infected hand wounds, immunodeficiency, or septic complications (lymphangitis, septic arthritis, or osteomyelitis) should be admitted. The recommended inpatient antibiotic regimen consists of penicillin G plus nafcillin or a first-generation cephalosporin. This combination of antibiotics provides coverage for staphylococci, streptococci, and most anaerobes (including *Eikenella*). For outpatient treatment, the patients can receive an initial parenteral dose of antibiotics (previously described) and are then discharged on a 7- to 10-day course of penicillin G plus dicloxacillin or amoxicillin/clavulanate. Patients allergic to penicillins and cephalosporins can be given azithromycin, clarithromycin, fluoroquinolones, or clindamycin.

Bite wound management

Most bite wounds are minor. Local wound care always begins with a thorough evaluation of the injury. The location, number, type, and depth of the wound is noted. The wound is also assessed for signs of infection. Bite wounds are frequently puncture wounds. Meticulous examination is of utmost importance, because these wounds are notoriously deceptive and may be more extensive than they initially appear [173]. The physician should evaluate all bite wounds for injuries to deep structures, such as tendons, joint capsules, blood vessels, nerves, and bone. Local or regional anesthetic should be used to facilitate wound exploration. A proximal tourniquet may be used when necessary to create a bloodless field. If bony involvement or foreign body is suspected, a plain radiograph should be obtained. Meticulous cleansing, irrigation, and debridement are the essential components of bite wound care. Irrigation of puncture wounds is controversial. Their small openings do not allow the irrigant solution to drain out appropriately, which may result in infiltration of the tissue. Surgical debridement may be necessary to remove compromised or necrotic tissue, which may contain embedded organisms, soil, and clots that cannot be removed by irrigation alone.

Primary closure of bite wounds

Recent studies support the primary closure of selected dog bite injuries [135,141,148,156]. In one study, 145 patients with dog bite wounds in the head and neck underwent primary closure [135]. Patients did not receive

Table 3
Recommendations for tetanus prophylaxis

History of tetanus immunization	Clean minor wounds Td	Clean minor wounds TIG	All other wounds[a] Td	All other wounds[a] TIG
< 3 or uncertain doses	Yes	No	Yes	Yes
≥ 3 doses				
Last dose within 5 y	No	No	No	No
Last dose within 5–10 y	No	No	Yes	No
Last dose > 10 y	Yes	No	Yes	No

[a] For example, contaminated wounds, puncture wounds, avulsions, burns, crush injuries.
Abbreviations: Td, tetanus-diphtheria toxoid; TIG, tetanus immune globulin.
From Centers for Disease Control and Prevention. Diphtheria, tetanus, and pertussis: recommendations for vaccine use and other preventive measures. Recommendations of the Immunization Practices Advisory Committee (ACIP). Mor Mortal Wkly Rep CDC Surveill Summ 1991;40:1–28.

prophylactic antibiotics. The bite wound infection rate was only 1.4%. This study supports the current recommendation not to use prophylactic antibiotics, even when the facial wounds are repaired during the initial ED visit [148,181,182]. Bite wound lacerations to the head and neck that are more than 1.5 cm in length can be closed primarily with sutures [143]. Small bite wounds (< 1.5 cm) behave like puncture wounds and should be left open to allow for drainage [189]. Patients with bite wounds that require reconstructive surgery should be immediately referred to the appropriate specialist. Hand wounds should be managed without immediate primary closure. For cosmetic reasons, facial wounds should be repaired. Other bite lacerations can be closed using delayed primary closure techniques. All injured extremities should be immobilized and elevated. Bites are tetanus-prone wounds and the recommendations of the Advisory Committee on Immunization Practices (ACIP) for immunoprophylaxis should be followed

Table 4
Recommendations for rabies postexposure prophylaxis in the United States

Animal type	Evaluation and disposition of animal	Postexposure prophylaxis recommendations
Dogs, cats, and ferrets	Healthy and available for 10 d of observation	Persons should not begin prophylaxis unless animal develops clinical signs of rabies.[a]
	Rabid or suspected rabid	Immediately vaccinate.
	Unknown (eg, escaped)	Consult public health officials.

[a] During the 10-d observation period, begin postexposure prophylaxis at the first sign of rabies in a dog, cat, or ferret that has bitten someone. If the animal exhibits clinical signs of rabies, it should be euthanized immediately and tested.
From Centers for Disease Control and Prevention. Human rabies prevention—United States, 1999. Recommendations of the Immunization Practices Advisory Committee (ACIP). More Mortal Wkly Rep CDC Surveill Summ 1999;48:1–23.

(Table 3) [183]. Domestic and wild animal bite victims should be assessed for the need for rabies postexposure immunoprophylaxis. The ACIP guidelines should be used in conjunction with local and state public health officials (Table 4) [184].

Summary

The goals of wound management are simple: avoid infection and achieve a functional and aesthetically pleasing scar [44]. This is achieved by reducing tissue contamination, debriding devitalized tissue, and restoring perfusion in poorly perfused wounds, in conjunction with a well-approximated skin closure.

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