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Pediatric Wound Care in the Emergency Department

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CLINICAL CHALLENGES

- What are the steps for initial evaluation of wounds in the pediatric population?
- How are wounds appropriately managed in pediatric patients?
- Which risk factors complicate wound repair and lead to poor outcomes?

Traumatic wounds and lacerations are common pediatric presenting complaints to emergency departments. Although there is a large body of literature on wound care, many emergency clinicians base management of wounds on theories and techniques that have been passed down over time. Therefore, controversial, conflicting, and unfounded recommendations are prevalent. This issue reviews evidence-based recommendations for wound care, including wound cleansing and irrigation, anxiolysis/sedation techniques, closure methods, and postrepair wound care.

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Target Audience: This enduring material is designed for emergency medicine physicians, physician assistants, nurse practitioners, and residents.

Goals: Upon completion of this activity, you should be able to: (1) identify areas in practice that require modification to be consistent with current evidence in order to improve competence and performance; (2) develop strategies to accurately diagnose and treat both common and critical ED presentations; and (3) demonstrate informed medical decision-making based on the strongest clinical evidence.

CME Objectives: Upon completion of this article, you should be able to: (1) recognize the etiologies of wounds; (2) describe the steps for initial evaluation of wounds in the pediatric population; (3) appropriately manage wounds in pediatric patients; and (4) recognize risk factors for wound repair complications and poor outcomes.

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Case Presentations

CASE 1

A 2-year-old boy presents with a forehead laceration that occurred when he tripped and fell onto the edge of a table...

- The boy is very upset and screams and turns away when you try to remove the bandage.
- The resident you are working with asks what sutures they should grab from the supply room. They also ask you what the best way is to handle toddlers who require local wound care...

CASE 2

A 12-month-old girl presents with 2 C-shaped lacerations on her upper arm with some surrounding bruising...

- The family reports that she fell.
- After evaluating the child and the wound, you have some concerns that this wound may have been inflicted.
- The medical student shadowing you asks why you think that...

Introduction

Wounds and skin injuries are among the most common presenting complaints to emergency departments (EDs). More than 6 million lacerations are treated each year in EDs in the United States.[1] Most children, at some point, are likely to sustain accidental trauma and minor wounds due to their developmental states, curious nature, and risk-taking behavior.

Despite a large body of literature on wound care, controversial, conflicting, and unfounded recommendations still remain.[2] Clinicians may develop their wound care practice based on dogma or word-of-mouth, and there is great variability among emergency clinicians on the preparation and treatment of wounds.[3] A widely accepted standard of care does not exist.

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Most wounds heal well, which is more likely due to the body's innate healing ability than to medical intervention. Nevertheless, it is prudent to know ideal methods and recommendations for wound care. This issue of *Pediatric Emergency Medicine Practice: Pediatric Trauma EXTRA* reviews major aspects of wound care, including cleansing, repair methods, and postwound care. Evidence-based recommendations are distinguished from unfounded traditional practices.

■ Critical Appraisal of the Literature

A search was performed in PubMed for articles pertaining to, but not limited to, children, using multiple combinations of the search terms *wound, laceration, traumatic wound, animal bite, human bite, tissue adhesive, cyanoacrylate, adhesive strips, staples, hair apposition*, and *antibiotic prophylaxis*. The Cochrane Database of Systematic Reviews was also searched and articles relevant to traumatic wound care were reviewed. Over 300 articles were reviewed, including a number of randomized controlled trials, meta-analyses, and clinical practice guidelines.

■ Etiology and Pathophysiology

The skin is a protective organ that promotes moisture and temperature regulation. Injuries to the skin require a complex and coordinated chain of events to regenerate skin cells and promote healing.[4] This process begins with an inflammatory phase that lasts 3 to 4 days after the injury, in which a platelet plug is formed to halt bleeding and begin cytokine signaling. During this process, neutrophils are drawn to the wound and assist in debridement. In the latter part of the inflammatory phase, macrophages become the predominant cell type and help to downregulate the inflammatory state to prevent pathologic inflammation.[4] During the proliferative phase, which occurs from days 4 to 21, angiogenesis, extracellular matrix formation, and epithelialization occur. Collagen production and deposition peak at the end of the proliferative phase.[4] The remodeling phase occurs from 3 weeks to 1 year after initial injury; during this phase, collagen remodeling and wound contraction occur. Collagen remodeling allows the wound tensile strength to increase; maximum wound strength occurs between 42 and 60 days after injury.

Wound healing may be impaired by poor oxygen delivery, which is often caused by patient-derived factors such as smoking, peripheral vascular disease, or poorly controlled diabetes.[4] While these factors are more prevalent in the adult population, the same principles apply to the pediatric population. Proper nutrition is also important, as wound healing is an anabolic process that imparts increased metabolic demand. Improved wound healing has been demonstrated in pediatric burn patients in whom early excision and aggressive feeding were performed. Patients with a deficiency in vitamin C have been shown to have a greater chance of wound infection.[4] There are also several inherited conditions that are associ-

ated with impairments in wound healing, including pseudoxanthoma elasticum, Ehlers-Danlos syndrome, and cutis laxa.

The phases of wound healing are influenced by the techniques employed during repair, as well as postrepair wound care. Wound cleansing is important, as bacterial inoculation of the wound or excessive debris can impede epithelialization.[5] Approximating the wound and maintaining a moist wound base can enhance the epithelialization process.[5]

Differential Diagnosis

The management of pediatric acute wounds generally requires little-to-no differential thought processing. The cause of the wound is typically identified while obtaining a history from the patient or the patient's family. In cases where the mechanism of the wound is unknown or not clear, the evaluation and treatment of acute wounds typically does not change. Nonaccidental trauma must remain in the differential, especially for preverbal children and when the reported mechanism does not match the injury.

Prehospital Care

The goals of prehospital wound care should be hemostasis and keeping the wound clean. Hemostasis may be achieved by applying pressure with clean bandages. If bleeding is difficult to control and the wound location is amenable to applying a tourniquet (ie, on an extremity), a tourniquet or a blood pressure cuff sufficiently inflated to control hemorrhage should be applied. Any visible foreign bodies should be left in place. If there is bleeding in or around the airway, suction should be used to keep the airway patent. Patients with significant trauma should be transferred to a pediatric trauma center.

Emergency Department Evaluation

History

When eliciting a history from patients or family members of patients with wounds, it is important to determine the timing and mechanism of injury. Many studies have tried to determine the time window in which primary closure of a wound is appropriate (discussed in the "Treatment" section, page 7). Details about the mechanism will help elucidate the extent of the injury. More severe mechanisms may have a higher likelihood of associated fractures, vascular injuries, or nerve injuries. Emergency clinicians should inquire about the possibility of contaminated wounds, including contact with saliva, debris, or foreign bodies. Inquiries should be made regarding the date of the last tetanus shot, allergies, and prior allergic reactions during wound repairs. Past medical history should be obtained, as certain pre-existing conditions may impair healing ability, and other conditions may make the actual procedure challenging (eg, autism and attention-

deficit/hyperactivity disorder). Conditions that impair wound healing include diabetes, immunocompromised states, steroid use, and obesity.

Physical Examination

Assessment of vital signs is important, especially in patients who may have significant blood loss. Tachycardia and hypotension are indicators of rapid and significant blood loss, although many children with wounds may be tachycardic because of fear and anxiety.

When examining children with simple wounds, a good strategy is to evaluate the wound last, as examination of the wound may be upsetting to the child. However, if there is concern for active or excessive bleeding or if there is concern for loss of limb, the area should be evaluated immediately after ensuring the airway, breathing, and circulation are intact. Exploration of wounds is best performed after the area has been appropriately anesthetized to avoid added discomfort. Assessing the neurovascular status of the involved area will help determine the extent of the injury. If there is evidence of neurovascular injury, a specialist should be consulted immediately, or rapid transfer to a facility where the patient can be evaluated and treated by a specialist should be arranged. Wound size, shape, and depth can usually be determined quickly. Some wounds may require gentle exploration to determine the depth of the injury and whether any deeper structures such as blood vessels, nerves, or tendons are involved. Gentle manipulation of the wound may help determine how the wound edges fit back together.

During the physical examination, emergency clinicians can get a sense of how well a patient will tolerate repair of the wound. Uncooperative patients may benefit from anxiolytic medications or even procedural sedation.

Diagnostic Studies

Most children with simple wounds do not require diagnostic studies; however, studies may need to be conducted for trauma patients, depending on the severity of the mechanism of injury.

Laboratory Studies

Laboratory studies are rarely useful in the management of acute wounds. A patient's past medical history or the circumstances surrounding the wound itself may indicate a need for further testing.

Imaging Studies

Radiographs may be indicated if there is concern for an underlying fracture or a radiopaque foreign body. If concern for a nonradiopaque foreign body remains, soft-tissue ultrasound may be useful. Echogenic material may be seen on ultrasound imaging, or a hypoechoic halo with reverberating shadows may be a clue to the presence of a foreign body.

Treatment

There are 3 types of wound healing: (1) primary closure (also known as healing by primary intention), (2) secondary closure (also known as healing by secondary intention), and (3) delayed primary closure (also known as healing by tertiary intention). Primary closure occurs when a small, clean cut can be approximated and closed with sutures, staples, tissue adhesive, adhesive tape, etc. Secondary closure occurs when the tissue is damaged or lost such that wound edges cannot be approximated and repaired, and a granulation tissue matrix fills in the wound. This type of healing takes longer and is more likely to scar. In the ED, most wound closures occur via primary or secondary intention. Occasionally, wounds are closed by delayed primary wound closure, where the wound is cleaned and observed for a few days before it is surgically closed. This method is often used when a wound is contaminated.

Timing of Wound Closure

Historically, the time from initial injury has been one of the biggest driving factors for determining whether wounds should be closed via primary or secondary intention. Classic teaching is that traumatic wounds should not be closed after 6 hours; this teaching is based on an 1898 study on guinea pigs. This dogma was challenged in a 1988 study by Berk et al, who determined that there was a 19-hour "golden period" for traumatic wound closure.[6] In that study of 204 adult patients, the authors found an infection rate of 7.9% in wounds closed before 19 hours compared to an infection rate of 22.6% in wounds closed after 19 hours.[6] However, head/facial wounds repaired after 19 hours healed without infection in 95.5% of cases. Of note, the authors used a single pair of sterile gloves and 1 set of instruments for multiple patients, which likely contributed to the infection rates.

Another study published in 2010 attempted to challenge the 6-hour dogma and found no difference in infection rates when wounds were closed >6 hours after injury.[7] This study included both cut and crush wounds on the head, torso, and upper and lower extremities. The majority (76%) of the wounds were superficial, 14% involved the subcutaneous tissue, and 8% were deep wounds.[7] In this study of 408 patients, only 5 patients presented >19 hours after injury, and, therefore, the authors could not compare their results to Berk's proposed 19-hour "golden period." Waseem et al found an increased rate of infection for wounds closed after 1000 minutes (16.6 hours).[8] Conversely, a multicenter prospective cohort study of 2663 patients found no association between the time of injury to the time of wound closure and the development of infection, and, therefore, no true "golden period."[9] In 2021, a systematic review included 9 studies to again assess if there is a wound age at which wound closure should not be attempted. The review could not identify such a time frame. For primary closure, a history of diabetes, the wound characteristics, and wound contamination were more important than the "golden period."[10]

Despite many attempts to establish an absolute time interval after which laceration repair should not be performed, there is no consensus in the literature as to what is an acceptable "golden period." General consensus seems to be with Berk; wounds on the head and neck can be closed after 19 hours, while wounds in other areas should be closed with caution after 19 hours. Most importantly, each patient should be treated individually and shared decision making with families is of utmost importance.

Wound Preparation

After determining to close the wound, it is time to prepare the area. Wound preparation consists of wound irrigation, cleansing, and antisepsis.

Wound Irrigation and Cleansing

The first step in traumatic wound management is irrigation, which both cleanses the wound and allows for thorough wound inspection.[11,12] Cleansing the wound is essential as it helps remove contaminants, debris, and microbes.[13]

Wound Irrigation Solutions

There are several options when choosing irrigation solutions, including normal saline, sterile water, or tap water. Normal saline is a preferred solution for wound irrigation, as it is isotonic and readily available. Hypotonic solutions, such as water, are thought to impair wound healing due to cell lysis. Sterile water is sterilized water without any added antimicrobial properties, packaged as an irrigant.[14] However, tap water may be used and is more cost-effective.[15,16] There is no evidence that using tap water to cleanse wounds increases infection rates, and there is some evidence that it may reduce infection rates.[17-19] However, if the local water supply is contaminated or there is concern for contamination, sterile water or saline is recommended. A 2022 Cochrane review of 13 randomized controlled trials with a total of 2504 participants compared wound cleansing with tap water, distilled water, cooled boiled water, or saline. The certainty of evidence in regard to which solution had effect on wound healing, cost, pain, or patient satisfaction was low, mainly due to inadequate sample sizes and study design.[20]

Wound Irrigation Volume and Pressure

As described above, Weiss et al found that water is an effective solution for wound irrigation. The randomized controlled trial used an 18-gauge IV attached to a 35 mL syringe to deliver 500 mL of water, generating a pounds per square inch (psi) of 8.[17] This does suggest that wound irrigation volume and pressure may be even more important than the type of wound irrigation solution. The optimal volume for wound irrigation, however, is understudied. The ideal volume is that which is sufficient to clear all debris from the wound. Volumes of 50 mL/cm to 100 mL/cm of laceration length are commonly reported.[21,22]

There is also no real consensus in the literature regarding the optimal pressure to use for wound irrigation.[23] Studies suggest that 5 psi to 8 psi is strong enough to overcome the adhesive forces of bacteria,[21,24,25] and pressures >15 psi may cause wound damage and impair healing.[26-28] There are numerous methods used in everyday practice for wound irrigation, including a needle attached to a syringe, piercing a bottle of fluids, a bulb syringe, a bag of intravenous fluids using a pressure bag, and a syringe with a shield or splash cap. The delivered pressure of these methods is listed in **Table 1**.

Table 1. Irrigation Methods and Delivered Pressure

Irrigation Method	Delivered Pressure
35-mL syringe and 19-gauge needle	35 psi from the needle,[29] 8 psi delivered to the wound[30]
65-mL syringe and 19-gauge needle	27.5 psi from the needle,[29] 8 psi delivered to the wound[30]
Bulb syringe	0.05 psi
1 L NS with pressure cuff (inflated to 400 mm Hg) and 19-gauge needle	6-10 psi[30]
1 L NS and 19-gauge needle	2-5.5 psi
1 L plastic bottle pierced with a 19-gauge needle	2-5.5 psi
Tap water from the sink	40-45 psi
Irrigation port or cap	2 psi[30]

Abbreviations: L, liter; NS, normal saline; psi, pounds per square inch.

Tap water from a standard water tap delivers approximately 40 psi to 45 psi and also delivers much higher volume.[31] Valente et al found no difference in wound infection rates when comparing tap water irrigation from the sink versus normal saline irrigation using a 30-mL to 60-mL syringe and an 18-gauge needle.[18] Patients in the tap water group received nearly 24 times the volume of irrigation fluid. Especially when considering hand and foot lacerations, which tend to have a higher overall infection rate,[32] the use of water from the tap may confer benefit based simply on the volume of irrigation fluid that can be delivered to the wound, rather than the pressure provided from the tap.

Higher-pressure pulsating jet irrigation, although not typically available in an ED, has been shown to reduce bacterial contamination in contaminated wounds.[33] High-pressure irrigation of contaminated wounds also remains controversial. While pressure irrigation may dislodge foreign bodies, tissue injury and the driving of particulate matter and/or bacteria deeper into wounds is also a concern.[34] Visualized foreign bodies or particulate matter may be removed with the use of forceps. Patients with retained foreign bodies after irrigation should be referred to a surgeon for follow-up.

There are few to no high-quality studies that demonstrate ideal fluid pressure for traumatic wound irrigation.[23] No matter which method is chosen, remember to wear personal protective equipment such as a face mask and eye protection to avoid body fluid exposure.

Antisepsis

The use of antiseptics for wound irrigation and cleansing is controversial. Some available antiseptics are iodine, povidone-iodine, hydrogen peroxide, and chlorhexidine. While potentially offering antimicrobial properties, antiseptics can have cytotoxic effects at the cellular level, potentially impairing wound healing.

There is conflicting evidence regarding the toxicity of iodine at the cellular level, as well as the clinical outcomes of wounds cleansed with iodine in terms of infection. Some studies have found significantly lower infection rates in wounds that were exposed to iodine.[35,36] Animal studies, however, have found iodine to be toxic to fibroblasts, granulocytes, and monocytes, whereas another study found an increased number of fibroblasts and enhanced angiogenesis when iodine was applied to a wound.[37-39] A study on diluted povidone-iodine found that solutions <0.1% did not have significant effects on cell migration and survival,[40] while another study demonstrated retarded fibroblast growth even with dilutions of 0.01%.[41] If used as an irrigation solution, povidone-iodine should be diluted to at least 0.1%. If used solely for antisepsis, after irrigation with saline or water, experts recommend painting it around wound edges only. Hydrogen peroxide and dilute sodium hypochlorite solution have also been found to be cytotoxic at the cellular level.[42] Chlorhexidine has significant antimicrobial effects but has also proven to be cytotoxic to cells in vitro.[43,44] When compared to iodine, however, a systematic review showed use of chlorhexidine preoperatively led to fewer positive skin cultures.[45]

A 2022 systematic review tried to compare several antiseptic agents including betadine and polyhexanide to either normal saline or Ringer's lactate. No practice-changing conclusions could be drawn from the review of 4 studies.[46] This shows that additional systematically sound in vivo studies are required to determine the optimal use of antiseptics for wound cleansing and irrigation.

Anesthesia

When treating children, minimizing pain and discomfort is of upmost importance. Historically, intradermal anesthetics have been the treatment of choice, but topical anesthetics have become much more popular and allow for painless anesthesia. A systematic review of 22 studies found that topical anesthetic preparations had equivalent or superior analgesic efficacy compared to conventional lidocaine infiltration.[47]

Topical Anesthesia

The first report of successful use of topical anesthetics was in 1980; the formulation comprises tetracaine, epinephrine/adrenaline, and cocaine (TEC or TAC).[48] This product gained widespread use across North America, but due to concerns of adverse effects related to cocaine, cocaine-free topical anesthetics were developed.[47,49] Lidocaine 4%, epinephrine/adrenaline 0.1%, and tetracaine 0.5% (LET or LAT solution) is the most commonly used formulation. It has been found to be as effective as TAC[50,51] and is a safer and less-expensive alternative.[47,52] LET comes in 2 preparations: a methylcellulose gel and an aqueous solution. LET gel can be applied directly to the wound or via a cotton-tipped applicator then covered with gauze or an occlusive dressing, such as a transparent film dressing. The gel should remain in place for 20 to 30 minutes then removed prior to wound repair.[50,51] LET solution can be applied into the wound with a cotton-tipped swab or soaked gauze, or a cotton ball can be placed in the wound and held in place for 20 to 30 minutes. Up to 3 mL of either formulation is the recommended dosing. No serious toxicity was reported with the use of this dose in a study of 203 children aged 3 months to 17 years.[53]

Due to the time required to achieve proper anesthesia, early application of LET is recommended. If additional analgesia is required after initial 30-minute LET application, further applications of LET have not been shown to result in lower pain scores during suturing.[54] LET is not recommended for use over mucous membranes (eg, the lips, mouth, or vulva), or in regions where there may be vascular compromise (eg, digits, the penis, ears, or nose). For oral mucosal lacerations specifically, a case series suggested dripping 3 mL to 5 mL of 1% injectable lidocaine into the wound. These 3 patients achieved local anesthesia after 5 minutes and tolerated the laceration repairs without any complications.[55] Application of topical anesthetics to simple wounds at triage can reduce total treatment time.[56]

Intradermal Anesthesia

Despite the popularity of topical anesthetics, injectable lidocaine is still often indicated, especially when time is a limiting factor. Lidocaine 1% without epinephrine is the most commonly used local anesthetic. Lidocaine with epinephrine may also be used, as it allows higher doses of anesthetic and decreases bleeding. The maximum doses of lidocaine are summarized in **Table 2 on page 12**. Similar to LET, lidocaine with epinephrine should not be used in areas of potential vascular compromise. However, there is some evidence that lidocaine with epinephrine is safe to use in digital nerve blocks in healthy patients without risk for poor peripheral circulation.[57]

Table 2. Maximum Lidocaine Dosage

Product	Maximum Dose	Maximum Volume
Lidocaine 1%	4.5 mg/kg of body weight	0.45 mL/kg of body weight
Lidocaine 1% with epinephrine	7 mg/kg of body weight	0.7 mL/kg of body weight
LET gel (lidocaine 4%)	–	0.18 mL/kg of body weight

Abbreviations: LET, lidocaine 4%, epinephrine/adrenaline 0.1%, and tetracaine 0.5%.

While injection of anesthesia may be painful, many studies have evaluated techniques to minimize discomfort. It is important to note, however, that pain perception varies among patients and is very difficult to study. Buffering lidocaine with bicarbonate to increase the pH has been found to decrease pain with infiltration.[58] Adding sodium bicarbonate to lidocaine in a 1:10 dilution is the standard formula for buffering lidocaine. Slower infiltration times reduce perceived pain and have a greater impact of lidocaine on pain infiltration than does buffering.[59] The wound should be injected from within the laceration rather than through intact skin.[60] This method is less painful and does not injure intact skin. Warming lidocaine to 40°C also results in less pain with injection.[61] Use of smaller-gauge needles, such as 27- to 30-gauge, also helps with pain perception.[5] Application of an ice cube to the injection site prior to injection for approximately 2 minutes can also reduce perceived pain.[62]

Nerve Blocks

Regional nerve blocks may also be utilized to anesthetize certain areas of the body and avoid distortion of the wound, both of which facilitate repair. Some of the most commonly encountered nerve blocks in the pediatric ED are digital blocks and facial nerve blocks. There are several methods for digital blocks, but the transthecal block may be preferable in pediatric patients, as it requires only 1 needle stick.[63] Emergency clinicians who treat pediatric patients should know how to perform mental and infraorbital nerve blocks. The mental nerve block anesthetizes the lower lip, the skin below the lip, and the chin. The infraorbital nerve block provides anesthesia to the upper lip, lateral nose, lower eyelid, and the medial portion of the cheek. The intraoral approach for both of these blocks is subjectively preferred by patients and results in lower pain scores.[64]

Anxiolysis/Sedation

Proper laceration repair is facilitated by having a cooperative patient. While older children may be able to tolerate repair without assistance, many children will be anxious and will require additional support to tolerate the procedure. Having the child's family stay with the patient may help to alleviate some anxiety as well.

When available, child life specialists should be present during procedures to help distract the child. Child life specialists employ several methods to assist children during procedures. A systematic review demonstrated that distraction and hypnosis were effective in reducing pain and distress related to procedures involving

needles.[65] If a child life specialist is not available, distraction with audiovisual devices can help with cooperation during procedures. A case report described the successful use of a surgical mask to create a visual barrier or "blinder" so that the child did not see the medical instruments or needles.[66] Utilization of immersive virtual reality has also been shown to be an effective distractive technique during laceration repair.[67]

When nonpharmacological techniques fail or are not sufficient, patients who require prolonged repairs or who are very uncooperative may require procedural sedation. Anxiolytic medications such as oral or intranasal (IN) midazolam can be used.[68] Midazolam is a GABA receptor agonist. The recommended dose of oral midazolam is 0.5 mg/kg, while the dose of IN midazolam ranges from 0.2 mg/kg to 0.5 mg/kg.[69-71] The maximum dose for oral and IN dosing is 20 mg and 10 mg, respectively. The IN method results in more rapid anxiolysis (approximately 10 minutes), but patients may experience a mild burning sensation during the administration.[69]

Intranasal dexmedetomidine is another studied anxiolytic medication. It is an alpha-2 agonist with analgesic, anxiolytic, and sedative properties. Studies have shown it to be less irritating to nasal mucosa compared to IN midazolam.[72] While it can have cardiovascular effects given its agonistic effect on alpha-2 receptors, it has an overall good safety profile.[73] One study showed that use of 2 mcg/kg of IN dexmedetomidine was associated with lower anxiety at time of positioning the child for laceration repair compared to 0.4 mg/kg of IN midazolam.[74]

Inhaled nitrous oxide, if available, has also been found to be safe and effective for minor procedures in children.[75] A randomized controlled trial found nitrous oxide was more effective and had fewer side effects compared to midazolam in children aged 2 to 6 years.[76]

In a 2020 prospective, double-blind, placebo-controlled study, utilization of oral hydrocodone/acetaminophen in adjunct with topical anesthesia led to lower pain scores in children aged 2 to 7 years.[77] In a 2024 systematic review on pharmacological agents used in procedural distress management during laceration repair in children, oral fentanyl was not favored by any of the 8 studies.[78]

Wound Closure

After anesthesia has been provided and the wound has been thoroughly irrigated, it is time for wound closure. Primary wound closure can be accomplished via a variety of means, including sutures, tissue adhesives, staples, adhesive strips, and hair apposition. The choice of suture materials depends upon the wound size, location, tension, depth, and clinician experience and comfort. Other considerations include the time required to perform the procedure and the level of pain inflicted by the method.

Gloves

Traditionally, wearing sterile gloves has been the standard of care for repairing wounds, but recent evidence has not shown any increase in infection rates when nonsterile gloves are used.[79,80] Sterile gloves are 3.5 to 15 times more costly.[81] Sterile gloves may still be preferred by some, as they offer a closer fit and more flexibility, but they are more costly than boxed gloves.

Needle Types

The needle types usually used in the ED are reverse cutting or conventional cutting needles.

Sutures

Suture Packaging

Suturing is the most used method for wound closure. Interpretation of suture packaging and selection of suture can be overwhelming. To better understand suture packaging, see **Figure 1**.

Figure 1. Suture Packaging

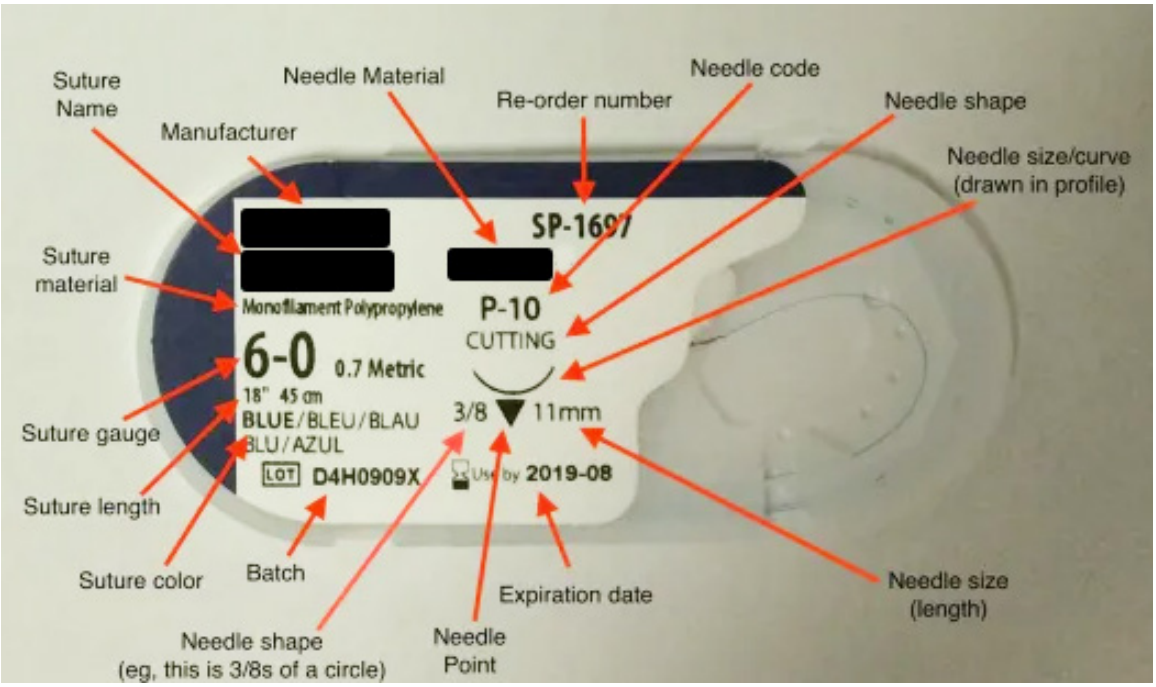

Image courtesy of Brian Lin, MD.

Suture Material

When considering using sutures for wound repair, first determine which type of suture to use, ie, absorbable or nonabsorbable. Absorbable sutures are made of collagen or synthetic polymers that are degraded by bodily enzymes, while nonabsorbable sutures are made from nonbiodegradable materials. Commonly available absorbable and nonabsorbable suture types are listed in **Table 3**. The advantage of absorbable sutures is the elimination of a return visit for suture

removal as well as avoidance of the discomfort of suture removal. Several studies have evaluated the cosmetic outcome and patient satisfaction with absorbable and nonabsorbable sutures and have found absorbable sutures to be noninferior to nonabsorbable sutures.[82] In a meta-analysis of 19 studies, there was no significant difference in the incidence of wound infections, rates of wound dehiscence, and cosmetic outcome between absorbable and nonabsorbable sutures.[82] Some studies have found that caregivers prefer absorbable sutures over nonabsorbable sutures.[83]

Another consideration in choosing suture material is filament type. Sutures come in either monofilament (single strand) or braided (multifilament) forms. **(See Table 3.)** Monofilament sutures have less inflammatory response than braided sutures but are more difficult to handle; braided sutures have greater tensile strength and maintain knot integrity more readily. The spaces between the braided sutures can also serve as areas for bacteria to deposit.

Table 3. Types and Properties of Suture Materials

Material	Size	Structure	Color	Time Retaining Tensile Strength	Use
Absorbable					
Chromic gut	3-0 to 7-0	Monofilament	Brown/blue dyed	21-28 days	Mouth, hands, feet, nailbed
Fast-absorbing gut	5-0, 6-0	Monofilament	Yellow/tan	5-7 days	Face
Fast-absorbing polyglactin 910 (Vicryl Rapide™)	1-0 to 5-0	Braided	Natural	5 days (50%)	Face, under casts, nailbed
Polyglactin 910 (Vicryl™); polyglactin 910 with triclosan (Vicryl Plus™)	3-0 to 8-0; 2-0 to 5-0	Braided	Natural/violet	21 days (50%)	Deep sutures
Wound adhesive	N/A	N/A	Light violet	N/A	Face, small lacerations under low tension
Nonabsorbable					
Nylon (Ethilon™)	2-0 to 11-0	Monofilament	Black/green/clear	N/A	All areas
Synthetic polypropylene (Prolene™)	2-0 to 10-0	Monofilament	Blue/clear	N/A	Extremities, joints
Staples	N/A	N/A	N/A	N/A	Scalp

Abbreviation: N/A, not applicable.

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Since wound infections are a commonly feared complication in wound repair, the idea of antimicrobial-coated sutures sounds appealing. While more research is

needed as it pertains to wound care in the ED, surgical literature has not shown lower rates of surgical site infections with antimicrobial-coated sutures.

Suture Size

In the United States, sizes of suture are standardized by the United States Pharmacopedia (USP), while the metric system is used in other countries. USP sizes range from 11-0 (smallest) to 7 (largest). The smaller the suture size, the lower the tensile strength. The tensile strength of the suture material should not exceed the tensile strength of the tissue.[84] Recommended suture size for different areas of the body as well as recommended time to suture removal are listed in **Table 4**. The most utilized suture sizes in the ED are 6-0 to 3-0.

Table 4. Recommended Suture Size and Duration by Location

Location	Size for Superficial Wounds	Size for Deep Wounds	Duration in Days
Face	5-0 or 6-0	5-0	3-5
Eyebrow	5-0 or 6-0	5-0	3-5
Trunk	4-0 or 5-0	3-0 or 4-0	7-10
Extremities	4-0 or 5-0	4-0	7-10
Joint surface	4-0	Not applicable	10-14
Hand	4-0 or 5-0	5-0 (tendon repair)	7-10
Foot sole	3-0 or 4-0	4-0	7-10
Fingers and toes	5-0	4-0 or 5-0	12-14

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Suturing Techniques

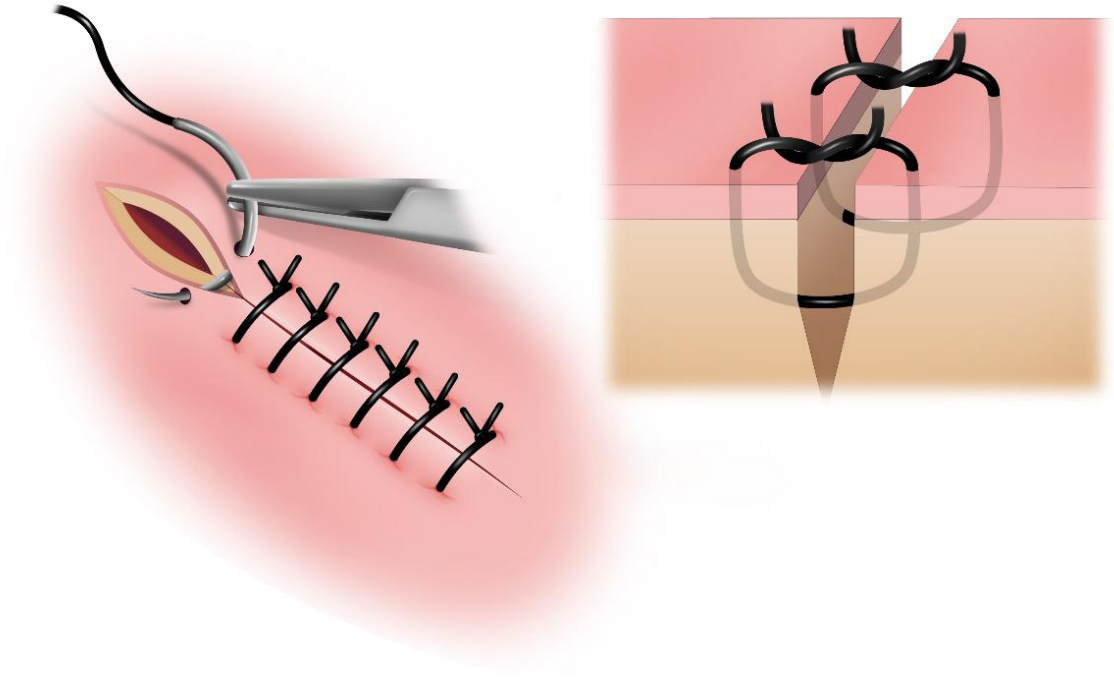
Simple Interrupted Suture

When to consider: In almost all situations with good approximation of wound edges

In the ED setting, simple interrupted sutures are used most commonly, and this technique is appropriate for most wounds. Simple interrupted suturing is easily mastered and offers the advantage of allowing adjustment or redoing of single sutures to achieve improved cosmetic outcome. The basic technique for simple interrupted suture placement involves inserting the needle perpendicular to the epidermis, traversing the epidermis and dermis using the curve of the needle, and exiting on the opposite side of the wound. Supination of your wrist allows you to follow the curvature of the needle. The entry and exit point of the needle should be symmetrically placed, in terms of width and depth. Once you exit on the opposite side of the wound, pull the suture through, leaving a small tail. The suture is then tied. To tie, use the instrument tying method. Bring your needle driver in between the entry and exit point and parallel to the wound. Using the long end of the suture (the end to which the needle is still attached), wrap the suture over the needle driver twice. While the long end of the suture is wrapped

around the needle driver, secure the short end of the suture with the needle driver. Gently pull both ends in opposite directions to lay the first knot flat. The consecutive knots are tied by wrapping the suture over the needle driver once. As a rule of thumb, use suture size for the number of knots (eg, make 5 knots using a 5-0). Then cut the suture. **(See Figure 2.)**

Figure 2. Simple Interrupted Suture



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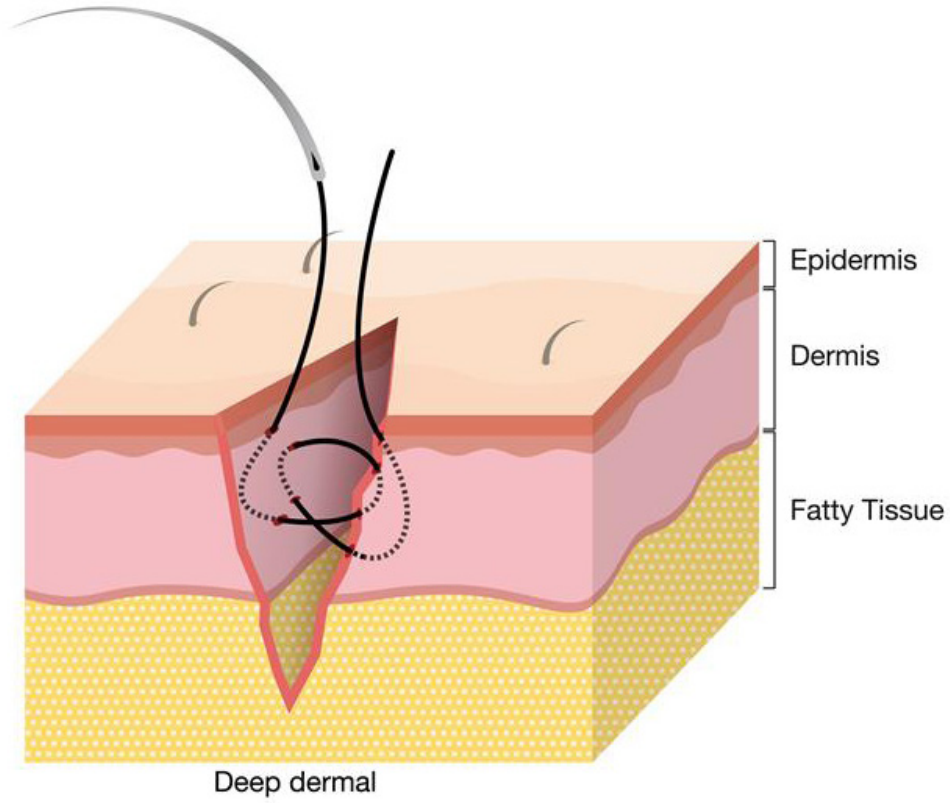
Deep Dermal Sutures

When to consider: To reduce tensile strength on a wound

To reduce tensile strength on a wound, sutures may need to be placed into the dermis prior to closing the epidermis. Absorbable sutures are always used for deep dermal sutures. The technique is very similar to that of the simple interrupted suture. Instead of entering superficially at the epidermis, however, the needle initially enters deep, through the deep dermis and then exits superficially on the same side, through the epidermis-dermis junction. After pulling the suture through the epidermis-dermis junction, reload the needle driver, and position the needle directly on the opposite side of the wound. This time, the needle enters superficially through the epidermis-dermis junction and exits deep, through the deep dermis. After pulling the suture through the deep dermis, ensure that both ends of the suture are on the same side. Use the instrument tying technique described above to tie. **(See Figure 3, page 18.)**

Figure 3. Deep Dermal Sutures



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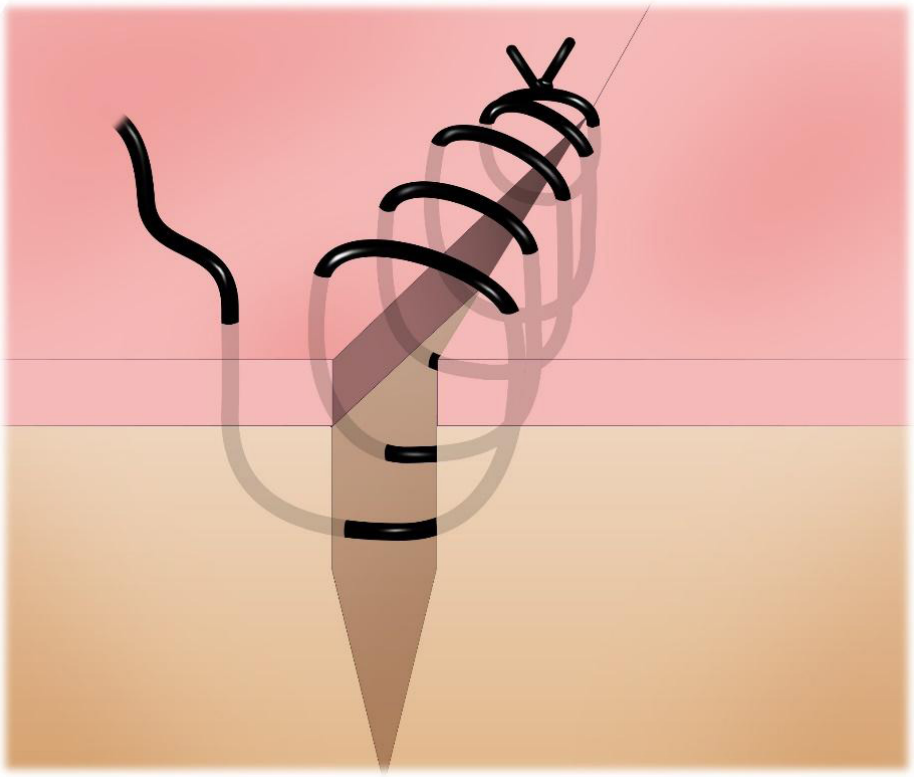
Running Suture and Locked Running Suture

When to consider: For wounds with minimal tension

Running sutures may also be used in the ED. A running suture is an uninterrupted series of simple interrupted sutures; therefore, the suture material is not tied or cut after each pass. A variation of a running suture is the locked running suture technique. A locked running suture is performed by passing the loop of the suture across the needle that has just passed through the tissue, then drawing the needle through until taut. In both running and locked running techniques, the final knot is made by leaving a small loop of suture material at the final bite and tying, using the loop and the tail. **(See Figure 4, page 19.)**

Because the suture material is not cut and tied with each suture, these techniques can result in faster wound closure. Running sutures allow even distribution of tension across the wound. The disadvantage of these techniques is that if a suture breaks, the integrity of the repair is lost, which may lead to wound dehiscence. Additionally, removing a single imperfect suture is not an option without disrupting the entire line.

Figure 4. Locked Running Suture



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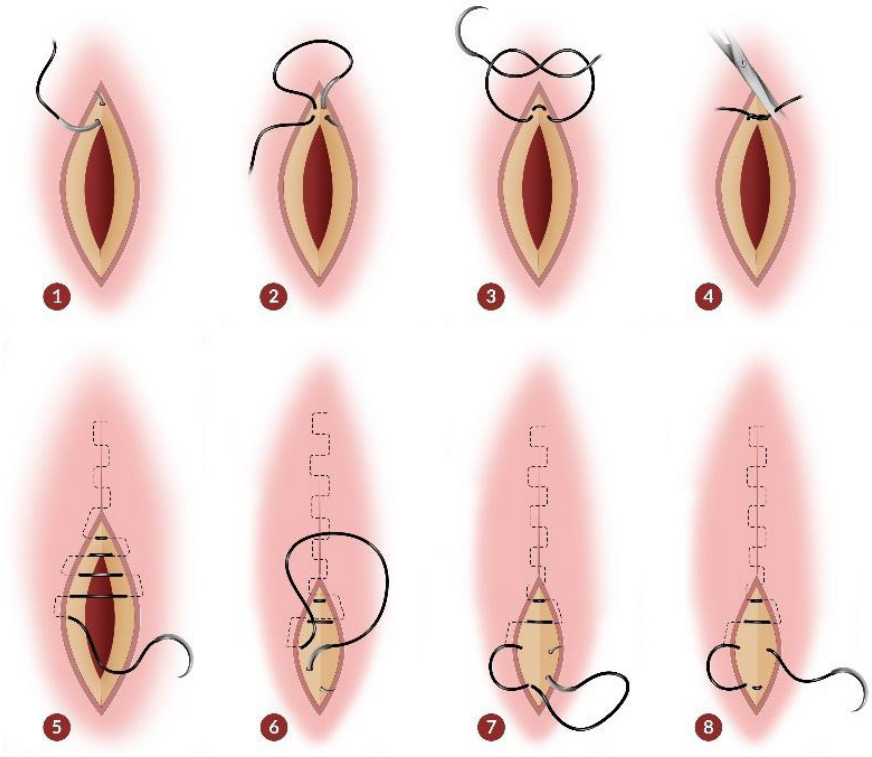
Running Subcuticular Suture

When to consider: linear wounds with minimal tension

The running subcuticular suture is an elegant method for wound repair but is the most technically difficult and is not often used by emergency clinicians. The advantage of this technique is that it eliminates the possibility of "hatch marks." This technique involves taking horizontal bites through the dermis on alternating sides of the wound. First, an anchor knot should be placed inside 1 of the far edges of the wound but without cutting off the needle. Then, horizontal bites are taken just below the epidermis on either side of the wound until near the edge of the wound. Once the last horizontal bite has been taken, a "loop" is left in the suture and is used as a tail to tie a knot. **(See Figure 5, page 20.)** This technique is much easier to learn if watched. A video demonstrating this technique is available at: www.ebmedicine.net/running-subcuticular

Figure 5. Running Subcuticular Suture



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Mattress Suture

When to consider: for areas under increased tension, such as over joints or palm

Vertical and horizontal mattress sutures can help distribute tension across a wound. The vertical mattress technique involves a simple interrupted stitch placed wide and deep into the wound edge, and a second more superficial interrupted stitch is placed closer to the wound edge and in the opposite direction. **(See Figure 6, page 21.)**

For the horizontal mattress technique, a suture is placed using the same technique as a simple interrupted suture, but instead of tying a knot, the needle re-enters the skin on the same side of the suture line 5 mm to 1 cm lateral to the exit point and passes to the opposite side of the wound where the 2 ends are tied. **(See Figure 7, page 21.)**

Figure 6. Vertical Mattress Suture

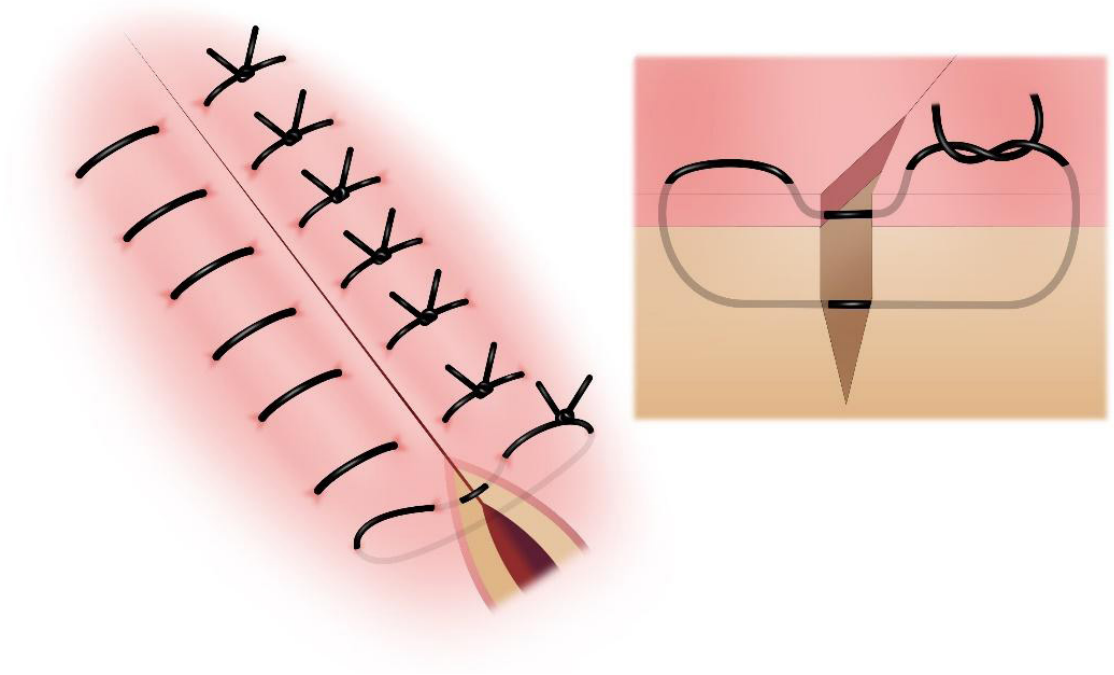

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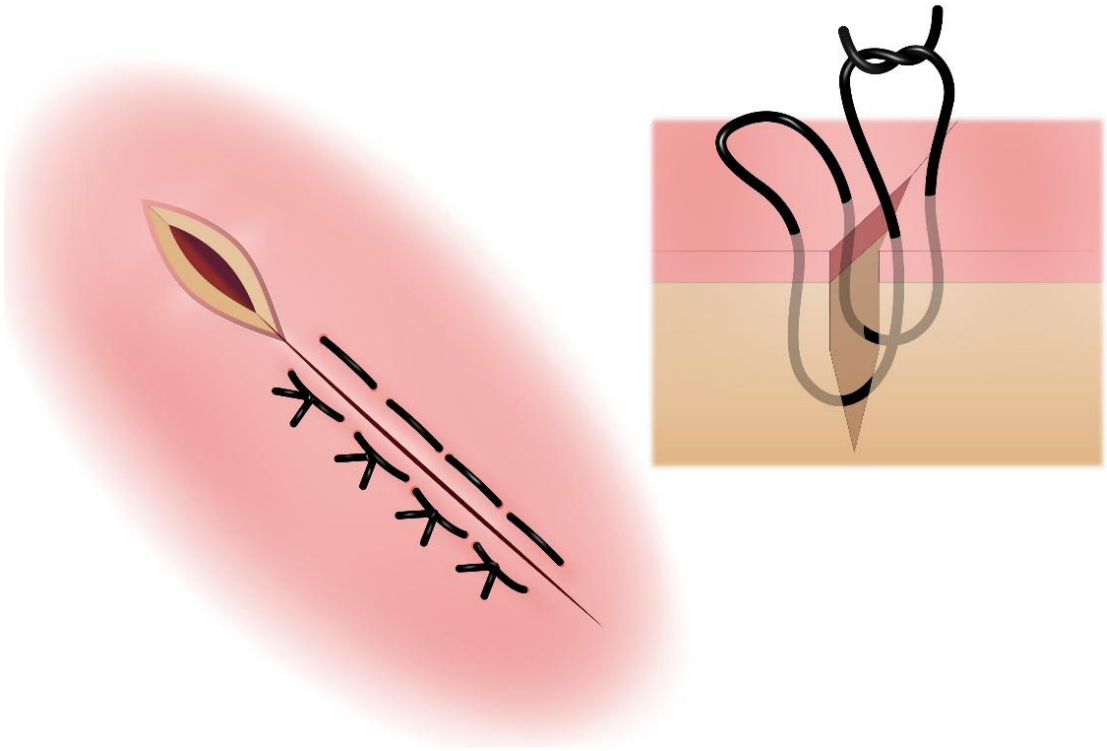
Figure 7. Horizontal Mattress Suture



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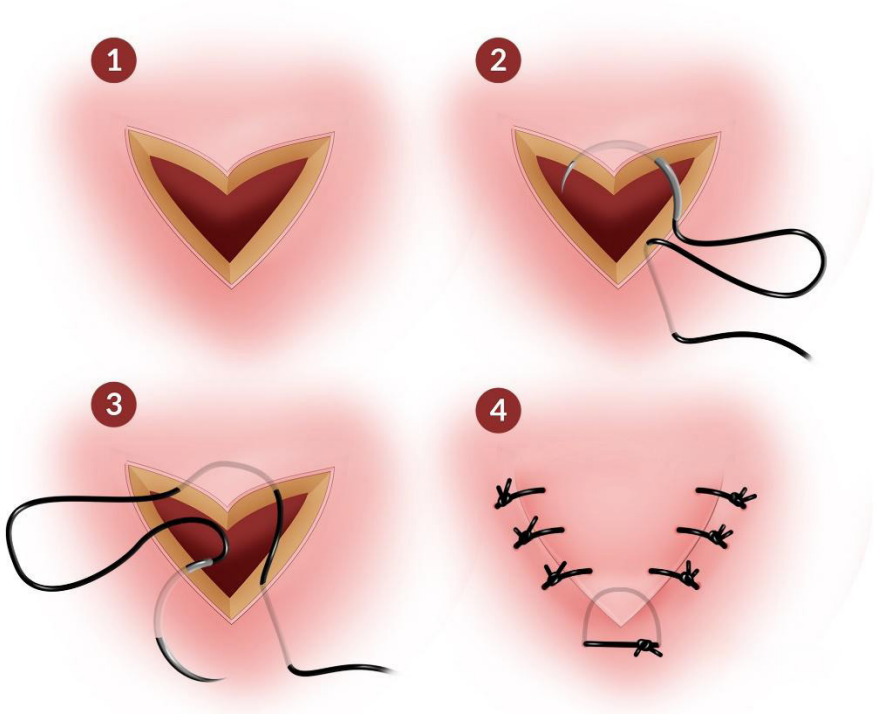
Corner Stitch

When to consider: "V" and "X" shaped lacerations with a flap edge

The corner stitch, or half-buried mattress, is the method of choice for these irregularly shaped lacerations. The corner stitch should be placed first, to approximate the flap edge, and then the remainder of the wound can be repaired with simple interrupted sutures. This technique is a variation of a horizontal mattress, in which the needle enters through intact skin, and then passes through the flap in the deep dermis and then exits again a few millimeters from the initial entry point and is then tied off. **(See Figure 8.)**

Figure 8. Corner Stitch



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Suture Spacing

To the best of our knowledge, suture spacing in traumatic wound lacerations in the ED has not been studied. In the surgical literature, a randomized clinical trial noted no difference in wound cosmesis or complications when comparing running cuticular sutures placed 2 mm versus 5 mm apart. In general, the fewer number of sutures and less space to approximate the wound well should be used. This will also depend on wound location, however. Areas of higher tension may require more closely spaced sutures.[85]

Eversion

When a wound heals, it tends to flatten out. Learners are often taught the concept of wound eversion, in which the edges of the wound are brought together

slightly everted or upward. The only study questioning this comes from the dermatology literature. The prospective, randomized, split-scar intervention had patients and other observers assess the scar at 3- and 6-month intervals after either eversion or planar repair. There was no favorable method based on the observer and patient assessment. Essentially, the most important part to remember when it comes to repair, eversion or not, is to minimize tension on the wound.[86]

Tissue Adhesive

Tissue adhesive compounds (made from cyanoacrylate derivatives) have been available for many years. The compound polymerizes quickly to keep approximated wound edges together. The compound is even antibacterial.[87] One of the most commonly used products, 2-octyl cyanoacrylate, is marketed as a replacement for sutures sized 5-0 or smaller. Studies comparing 2 different tissue adhesives, butylcyanoacrylate and octylcyanoacrylate, showed no difference in cosmesis, pain, time to completion of repair, and adverse effects for repair of pediatric facial lacerations.[88] Tissue adhesive compounds are ideal for linear lacerations in which the wound margins can easily be approximated. For wounds that are appropriate for cyanoacrylate derivatives but are more difficult to approximate, application of adhesive strips under the compound can be useful and can lead to similar cosmesis.[89] Tissue adhesive can be used in conjunction with, but not in the place of, deep dermal sutures. Tissue adhesives are not recommended for use on animal-bite repairs, stellate wounds, infected wounds, mucosal surfaces, or areas of high moisture or dense hair.[90] Tissue adhesive can be used on hands, feet, and in areas of tension as long as that area can be immobilized.[91-94]

During application, the wound should be held so that the margins are approximated prior to tissue adhesive application. Care should be taken to keep the wound margins approximated while the tissue adhesive is being applied, to avoid adhesive getting into the wound. Tissue adhesive within a wound will prevent epithelialization, and foreign-body reactions may occur.[91] Additional layers of tissue adhesive may need to be applied, depending on the brand of tissue adhesive used.

If tissue adhesive accidentally drips onto the patient or into the wound, it should be wiped immediately with dry gauze. If the tissue adhesive has already polymerized, petroleum-based products (eg, petroleum jelly or bacitracin) can be applied for 30 minutes, which will aid removal.[92] Acetone can also be used for tissue adhesive removal, but it will burn and sting if applied to a wound.[95]

For wounds around the eye, petroleum-based products can be used as a barrier to prevent tissue adhesive from dripping into the eye. If an eye is inadvertently "glued shut," ophthalmic antibiotic ointment can be placed on the eyelashes, which will help to remove the adhesive.[92] The eye should not be pried open, as it

may injure the eyelid margin and eyelashes may be pulled out. Tissue adhesive is unlikely to cause injury to the cornea.[96]

The advantages of tissue adhesive are quick application, minimal discomfort, and no follow-up required for removal.[97,98] No dressing is necessary for tissue adhesive, unless the child will pick at the adhesive, in which case a bandage or gauze may be necessary. A bandage should be applied only after the tissue adhesive has completely polymerized and is dry to the touch. Antibiotic ointments and creams should not be applied over tissue adhesive, as they can weaken the adhesive. Tissue adhesive can be splashed with water, but should not soak, as prolonged exposure to wetness may cause early sloughing of the adhesive.[92] Most tissue adhesives will naturally slough off after 5 to 10 days. There are no significant differences in short- and long-term cosmetic outcomes when tissue adhesives are used, as compared to standard wound closure.[88,90,99-101] In a 2022 systematic review, 1 study did find a small but statistically significant risk for wound dehiscence with tissue adhesive versus standard wound closure. Again, no difference was found between cosmesis, and pain scores and procedure length continued to favor tissue adhesives.[88] Tissue adhesives are also cost-effective.[102]

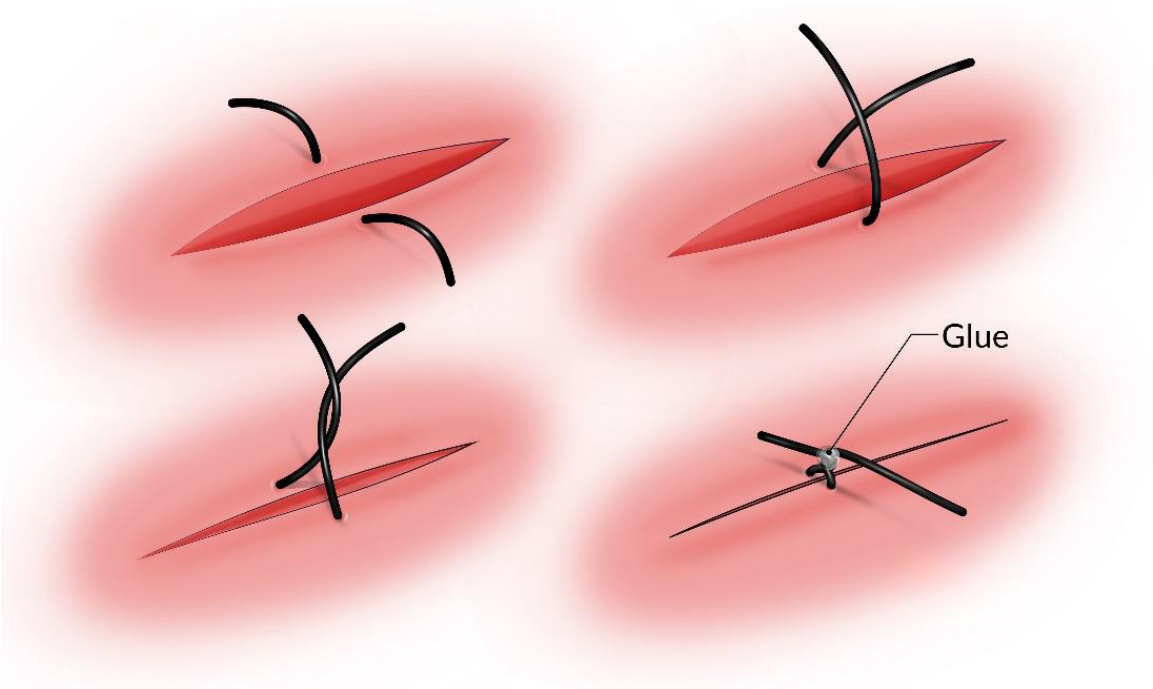
Staples

Stapling is the preferred method of closure for scalp lacerations. Staples have been used extensively in the operating room but tend to be used predominately for simple scalp lacerations in the ED. Use of staples results in shorter wound-closure times, shorter length of procedure, and is less costly.[103] One study demonstrated a 3-fold decrease in procedure time and no significant difference in cosmetic outcome at 6 to 18 months, as compared to sutured wounds.[104] A novel staple-like device has been approved by the United States Food and Drug Administration for use as a surgical staple. It is an adhesive with microstaples that attaches to the skin and allows for uniform tension. A small noncomparative study showed satisfactory cosmetic outcomes at 90 days for lacerations <10 cm on varying sites (scalp, face, forehead, extremity) in adults aged <18 years.[105] More studies are needed comparing this device to other wound closure options.

Hair Apposition

An alternative to sutures or staples for scalp laceration is hair apposition. Hairs on either side of the wound are twisted and then secured with a drop of tissue adhesive.[106,107] **(See Figure 9, page 25.)** This technique requires hair to be at least 1 cm long. A retrospective observational study demonstrated better cosmetic outcome and fewer complication rates using the hair apposition technique when compared to other techniques.[108]

Figure 9. Hair Apposition Technique



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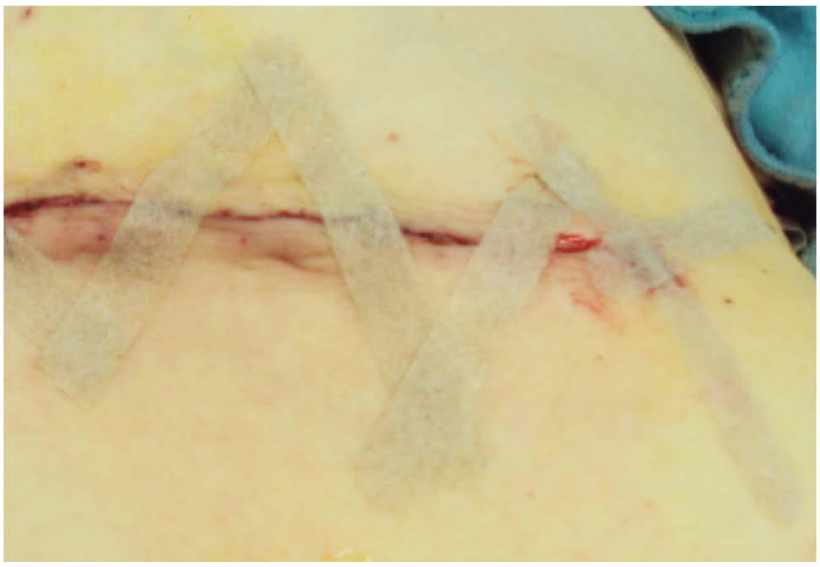
Adhesive Strips

Adhesive strips have long been used as a method of wound closure, as an adjuvant to reinforce a wound that is closed via sutures, or after suture or staple removal, as added wound support.[109,110] The advantage of adhesive strips is quick, painless, needleless application. Adhesive strips should not be used in areas of dense hair. Typically, adhesive strips are applied perpendicular to the wound, with tension. Adhesion may be aided by the use of a topical adhesive such as benzoin.[110] The strips should not overlap each other when placed perpendicular to the wound, and tacking strips (placing a strip at the edge of the strips running across the wound to keep the edges from peeling) have not been shown to offer any benefit.[109] An Italian study proposed a novel "zig-zag" technique for adhesive strip placement that distributes the tension across the wound, which allows the underlying wounds to be visible, allowing for the early detection of wound infection.[111] **(See Figure 10, page 26.)**

Figure 10. Zig-Zag Technique



Reprinted from Marco D'Ettorre, Roberto Bracaglia, Stefano Gentileschi, et al. A trick in steri-strips application: the zig-zag pattern. *International Wound Journal.* 2015:12(2):233, © 2015, with permission from John Wiley and Sons.

Two small studies have shown that approximation of a wound with adhesive strips, followed by suturing through the strips, has shown benefit, especially in thin-skinned patients.[112,113] Studies have demonstrated similar cosmetic outcomes between tissue adhesive and adhesive strips.[95,98] Analysis of cost-effectiveness has demonstrated that adhesive strips are a cost-saving and cost-effective alternative to both sutures and tissue adhesives.[114]

Zipper-Like Device

A number of zipper-like devices are now in the market. These are noninvasive devices used for wound closure. After application of the wound closure device, pulling of the straps helps to pull the wound edges together and distribute tension across the wound. More studies are needed assessing cosmesis outcomes and wound infection rates when such devices are used in pediatric lacerations.

Oral Antibiotic Prophylaxis

Once the wound is closed, it is time to think about infection risk again. Infection occurs in approximately 2% to 5% of all sutured wounds.[79,115] Wound infection is best prevented by thorough wound cleansing and appropriate closure method.[116] Due to the low infection rates, prophylactic antibiotics are not routinely recommended.[117-120] A meta-analysis comparing 9 studies found no evidence for prophylactic antibiotics for simple traumatic lacerations.[121] Even for wounds on the hand, which are generally thought to have an increased risk of infection, there was no convincing trend toward benefit of prophylactic systemic antibiotics.[122] The same is true for intraoral lesions.[123]

Despite these recommendations, a study of antibiotic-prescribing practices of emergency clinicians for uncomplicated lacerations found that 21% of patients were treated with antibiotics.[124] Clinicians were more likely to prescribe antibiotics for wounds >8 hours old, for puncture wounds or amputations, or in patients who did not have medical insurance.[124]

Certain types of wounds are more likely to develop infection. Some experts recommend antibiotic prophylaxis for wounds at high risk for infection.[2,125,126] The factors associated with increased risk of infection are listed in **Table 5**. While the list of high-risk wound characteristics is quite extensive, limiting antibiotic use to patients who are immunocompromised, have contaminated wounds, open fractures, bites, and extension to a sterile site is a reasonable approach. Most simple lacerations do not require empiric antibiotics. However, through-and-through lip lacerations (those that extend from the wet mucosa to the dry mucosa or skin) and those with significant mucosal involvement may benefit from prophylactic antibiotics such as amoxicillin, cephalexin, or clindamycin, to cover oral flora.[127]

Table 5. High-Risk Wound Characteristics[22,127]

Host Factors
- Extremes of age
- Diabetes mellitus
- Chronic renal failure
- Obesity
- Malnutrition
- Immunocompromised state

Wound Factors
- High bacterial content
- Soil contamination
- Crush injury
- Stellate laceration
- Sterile site (eg, joint)
- Deep wound
- Associated fracture
- Bite injury

Treatment Factors
- Use of epinephrine-containing solution
- Greater number of sutures
- Less-experienced physician

Tetanus Prophylaxis

All traumatic wounds are potentially at risk for tetanus infection, and, therefore, all patients should be assessed for tetanus immunization status. Tetanus immune globulin should be administered for tetanus-prone wounds.[128] **(See Table 6, page 28.)**

Table 6. Post Wound Tetanus Vaccination Guidelines

Vaccination History	Clean, Minor Wounds		All Other Wounds	
	DTaP, Tdap, or Td	TIG	DTaP, Tdap, or Td	TIG
Unknown or <3 doses	Yes	No	Yes	Yes
≥3 doses	No (unless >10 years since last booster)	No	No (unless >5 years since last booster)	No

Abbreviations: DTaP, diphtheria, tetanus, and acellular pertussis; Td, adult tetanus and diphtheria; Tdap, combined tetanus, diphtheria, and pertussis; TIG, tetanus immune globulin.
Adapted from: Centers for Disease Control and Prevention. *Epidemiology and Prevention of Vaccine-Preventable Diseases.* Hamborsky J, Kroger A, Wolfe S, eds. 13th ed. Washington D.C. Public Health Foundation, 2015.

Postrepair Wound Care

Postrepair wound care instructions are important to review with families prior to discharge from the ED. Common questions that families ask are whether the wound should remain dressed, whether the wound can get wet, and whether a cream should be applied to the wound.

Topical Antibiotics

Some commonly used topical antibiotics include bacitracin, polymyxin B/bacitracin/neomycin, and mupirocin. Topical antibiotic use is common practice in the ED.[3] One study found topical and systemic antibiotics to be equally effective at preventing wound infection.[129] In a double-blinded, randomized controlled trial, Dire et al studied the differences in infection rates in patients with uncomplicated wound infections managed with prophylactic bacitracin zinc; neomycin sulfate, bacitracin zinc, and polymyxin B sulfate combination (triple antibiotic ointment); silver sulfadiazine; and petrolatum.[130] Subjects applied the provided topical therapy 3 times a day until the sutures were removed or until they developed an infection. The infection rates were significantly lower in the bacitracin zinc and the triple antibiotic ointment groups.[130] In addition to preventing infection, the application of ointment-based products promoted wound healing by maintaining a moist environment, and it helped to facilitate suture removal.[131] A Cochrane review investigating whether topical antibiotics prevent surgical site infections in wounds healing by primary intention showed they probably do. Due to a small sample size, they could not conclude adverse events associated with the use of topical antibiotics.[132] Ointments and petroleum-based products should not be used over tissue adhesives, as they break down the adhesive. Whether ointments and petroleum-based products degrade absorbable sutures has not been studied, to the best of our knowledge.

Wound Dressing

Traditionally, bandages are placed and the wound should be clean and dry for 24 hours. Ideally, nonadherent dressings should protect a wound from bacterial contamination and provide a warm, moist environment that can stimulate wound-bed healing.[133,134] However, it has not been proven that dressings are capable of preventing bacteria access.[135] One study of 451 children demonstrated no increase in wound infection rates when the wound was left exposed versus dressed.[136] However, children may pick at or play with wounds that are uncovered, which may lead to increased infection rates.

Discharge Instructions

Sutures can get wet within the first 24 to 48 hours without increasing the risk of infection.[137,138] Some studies suggest that wounds may be washed within 8 hours of repair without increased risk of infection.[139] Patients are often advised to not soak wounds, and, therefore, to avoid bathing or swimming. In a 2006 trial, 857 patients were randomized to early versus delayed bathing or showering.[137] There

was no increased rate of infection in the early group (bathing within 48 hours of wound repair),[137] but further well-designed studies are needed to provide conclusive evidence.[140]

Avoiding sun exposure may help to prevent abnormal pigmentation, but there is little research regarding the duration and overall benefit of this recommendation.[141]

Special Circumstances

Specialist Consultation

While most wounds can be managed in the ED, there are situations in which specialist consultation should be sought. These include wounds with significant cosmetic concerns, eyelid injuries involving the lacrimal duct canaliculus and lid margin, deep injuries to the hand, joint involvement, extensive genitourinary injury, and extensive wounds requiring general anesthesia for repair. In cases where a specialist repairs a wound, involvement of the emergency clinician remains important, as the child may still require anxiolysis or sedation for the wound to be closed.

Given the relatively large head-to-body ratio of children, head and facial injuries are quite common in the pediatric population. Most of these injuries can be easily repaired by the emergency clinician. Jagged, abnormally shaped, or particularly large wounds on the face may benefit from consultation with a plastic surgeon. Wounds through the vermilion border require special attention, as the border needs to be perfectly approximated to avoid a noticeable scar and deformity of the lip. These wounds can be repaired without specialist consultation; however, if the treating clinician is not comfortable that an adequate approximation will be possible, a specialist should be consulted, as poor repair can produce obvious deformity.

Full-thickness nasal lacerations should be repaired by either a plastic surgeon or otolaryngologist, as the alar rim often heals with notching.[142] Lacerations to the ear that involve lacerated cartilage may also benefit from specialist care. Care should be taken to cover all exposed cartilage. If the cartilage is fully transected and requires reapproximation, the sutures should include the cartilage as well as both the anterior and posterior perichondrium to avoid tearing the cartilage. Full-thickness eyelid laceration, injuries to the tarsal plate, or injuries involving the tear duct should be repaired by an ophthalmologist.

Hand injuries require a thorough neurologic examination to assess for tendon and neurovascular injury. In 1 study, 16% of pediatric hand injuries required consultation with a specialist and tendon injuries were found in 2 of 382 patients (0.5%).[143]

Genital injuries may or may not require surgical or subspecialist consultation. In a study of female genital injuries, nearly half of the patients received gynecologic consultation and nearly 20% required operative management.[144] In boys with superficial scrotal injuries that do not extend through dartos fascia, repair can be performed by emergency clinicians. Extension through dartos fascia, urethral injuries, and injuries to the shaft of the penis are best managed by a specialist.

Bite Wounds

Bite wounds account for approximately 1% of all ED visits; more than half of those bites occur in children.[145] Dog bites are the most common animal bite seen in the ED each year. Recent reports suggest that there are upwards of 4.5 million dog bites per year.[28] Dog bites tend to cause crush injuries (due to the strength of the dog's jaws), which can result in damage to the skin and deeper tissue such as bones, vessels, muscles, and tendons. Cat bites, though less common than dog bites, can be more difficult to treat, as the sharp, pointed teeth of cats cause puncture wounds that can inoculate deep tissues with bacteria. Compared to dog bites, cat bites have an increased risk of infection (50% vs 10%-15%).[146] Common pathogens isolated from infected dog and cat bites include *Pasteurella* species, *Streptococcus* species, *Staphylococcus aureus*, *Capnocytophaga* species, *Moraxella* species, and anaerobes such as *Fusobacterium* and *Bacteroides*.[147] Refer to the *Pediatric Emergency Medicine Practice EXTRA!* supplement, "Mammalian Bite Wounds in Children: Evidence-Based Management in the Emergency Department" for a full discussion on ED management and treatment of animal and human bite wounds in children.

History and Physical Examination for Bite Wounds

When evaluating patients who present with bite wounds, it is important to note the time of the event, the type of animal, the circumstances surrounding the bite (ie, whether the animal was provoked), and the rabies vaccination history of the animal. The patient's tetanus status and medical history should also be obtained. If the bite was from any rabies-prone, unobservable wild or domestic animal with unknown immunization status, assessment of rabies risk to the patient needs to be performed, and rabies immunoglobulin and rabies vaccinations administered. The local health department and animal control can assist in determining the local risk. Fresh bite wounds do not need to be cultured initially, but cultures should be obtained if the wound becomes infected. Many states have a designated dog-bite reporting system. In states without dog-bite reporting systems, a report can be filed with the local health department or the police department.

Treatment of Bite Wounds

Bite wounds should be irrigated well and debrided, if needed. Due to the concern for increased risk of infection with primary closure, there is some debate in the literature as to whether dog bites should be closed primarily or allowed to heal by secondary intention. Deep laceration and puncture wounds should not

be closed primarily, but primary closure may be considered for facial wound. Bite wounds on the face have decreased rates of infection, and, in prospective randomized trials, have better cosmetic outcome without increased risk of infection with primary closure.[148] A recent randomized prospective cohort study found that there was no difference in infection rate between sutured and nonsutured superficial wounds, regardless of the location.[149] A meta-analysis that included 5 studies demonstrated similar findings.[150] Bites from a rabid animal should not be sutured closed.[146]

Mammalian bites are often cited as a contraindication to the use of tissue adhesives or cyanoacrylate for wound closure.[92] However, there is no evidence in the literature to support this claim.

Prophylactic antibiotic therapy is recommended for the prevention of wound infection from dog bites in patients who are immunocompromised (including those with asplenia), have advanced liver disease, have edema of the affected area, have moderate-to-severe injuries (especially on the hand or face), or have puncture wounds, especially if there is penetration of the periosteum or joint capsule.[151] Consider treatment of cat-bite wounds based on the nature of the bites. A 3- to 5-day course of amoxicillin-clavulanate is recommended.[152] Alternatives for penicillin-allergic patients include an extended-spectrum cephalosporin (such as cefdinir) or trimethoprim-sulfamethoxazole, along with clindamycin.[146]

Human Bites

Human bites, like cat and dog bites, are polymicrobial, but the human mouth can contain as many as 190 species of bacteria. The most common pathogen in human bite wounds that leads to infection is *Eikenella corrodens*.[153] Human bites also pose a potential threat for transmission of systemic infections such as hepatitis B and HIV. These bites tend to occur as either clenched-fist injuries or occlusive bites. Clenched-fist injuries are more common; these occur when a closed fist strikes the teeth of another (ie, fight bite), which can result in bacteria being drawn into the joint capsule by the extensor tendon. Occlusive bites occur when a person is bitten with enough force to break the skin. These bites can occur anywhere on the body. While many bites are accidentally or intentionally inflicted during a fight, child abuse should be considered in the differential of any child who presents with a human bite. All bite wounds should be measured to determine the intercanine distance. Normal adults have an intercanine distance of 2.5 to 4 cm, so any bite that falls within that intercanine distance is suspicious for abuse. As many as 10% to 15% of human bites become infected; therefore, all human bite wounds should be treated with antibiotics that are active against both aerobic and anaerobic bacteria (such as amoxicillin-clavulanate).[154] Tetanus vaccination status should be elicited and updated, if needed.

Surgical Site Infections

Wound infections or surgical site infections (SSIs), are some of the most common adverse events in hospitalized surgical patients.[155] Superficial incisional SSIs tend to occur within 30 days of the surgery, while deep incisional infection may occur from 30 days to 90 days after the surgery, depending on the type of procedure done.[156] SSIs present with pain, swelling, erythema, and/or purulent drainage. In patients for whom SSI is a concern, sutures should be removed and the area should be incised and drained. Cultures of exudate (if present) should be taken. Systemic antibiotics therapy is not routinely indicated[157] but may be used as an adjunct to incision and drainage in those who have a significant systemic response, including erythema extending >5 cm from the wound margin, fever, tachycardia, and a white blood cell count >12,000/dL.[151] If methicillin-sensitive *S aureus* is suspected, a first-generation cephalosporin or antistaphylococcal penicillin is recommended.[151] Vancomycin, clindamycin, or linezolid is recommended in cases of methicillin-resistant *S aureus* infection.[151] If available, institutional antibiograms should be consulted to determine optimal antibiotic therapy based on local resistance patterns.

■ Controversies and Cutting Edge

Honey

Honey has been used for thousands of years in wound care. There is some evidence that honey may accelerate wound healing.[158] Manuka honey is of particular interest, as it has antibacterial activity independent of the hydrogen peroxide effects found in most honeys.[159] Manuka honey, however, is quite expensive, averaging around $30 for a 250-gram jar. A Cochrane review evaluated 26 trials, 3 of which involved using honey in minor acute wounds.[158] While there is quality evidence that honey heals partial-thickness burns more quickly than conventional dressings, there is no convincing evidence that honey heals minor wounds faster than traditional dressings.[158]

Scar Management

Patients and families are often concerned about scar formation and management. Application of a sunscreen of SPF 30 or higher is commonly recommended after the wound has healed to avoid scar discoloration from sun exposure. Vitamin E may also be recommended to help reduce scar formation. One study found that approximately 36% of providers recommend vitamin E to patients.[160] However, a systematic review of 6 studies found that 3 studies reported cosmetic improvement and 3 demonstrated no improvement when using vitamin E monotherapy.[161]

Silicone sheets or gels have shown benefit in the prevention of hypertrophic scarring.[162] Two studies found silicone gel and sheets to be superior to onion extract gel, which is another topical agent marketed for scar reduction.[163,164] There are

many hypothesis as to how silicone affects scar formation. It is believed to influence collagen remodeling.[165] Silicone creates an impermeable membrane that provides increased local hydration. It is the hydration, not necessarily the silicone itself, that inhibits fibroblasts, and therefore affects collagen formation.[166] This suggests that the utilization of silicone sheets or gels can make scars softer, smoother, and flatter.[167]

Disposition

The majority of patients who present to the ED with minor wounds and lacerations can be discharged home with follow-up with their primary care provider. Patients should be informed of wound-care instructions and should be told when to follow up if sutures or staples require removal, noting that some primary care clinicians may not feel comfortable removing sutures or may not have a staple extractor device to remove staples. A 2-day wound check may be beneficial for patients with complicated repairs, contaminated wounds, or wounds on their hands or feet.

Patients may require inpatient admission if there are systemic signs of infection, if the patient has an immunocompromised status, or if the wound(s) require operative repair. Patients with wound infections for whom outpatient therapy fails may require admission for intravenous antibiotics.

Summary

Wound management is an important skill for emergency clinicians. Although skin closure is the primary goal, good anesthesia, wound irrigation, and management of patient anxiety and parental concerns are equally important. When possible and if appropriate for the wound, needleless methods for laceration repair should be utilized, as they are more cost- and time-effective and have cosmetic outcomes similar to sutures. Patients and families should be provided with clear instructions on how to care for the wounds at home and indications to return to the ED.

Time- and Cost-Effective Strategies

- **Use of tissue adhesive, absorbable sutures, or adhesive strips may prevent the need for a follow-up visit.** Noninvasive laceration repair techniques such as tissue adhesive and adhesive strips also result in shorter procedure times. One study extrapolated a national Medicare cost savings of approximately $215,000,000 per year with the use of absorbable sutures.[168]

- **Most wounds do not require antibiotic prophylaxis.** A meta-analysis of 7 trials involving simple wounds found that prophylactic antibiotics were not associated with decreased rates of infection.[121] Inappropriate use of antibiotics is costly and may cause adverse events and promote bacterial resistance.[169]

Case Conclusions

CASE 1

For the 2-year-old boy with a forehead laceration...

You explained to the resident that while the wound can be closed with sutures, its location on the forehead, linear shape, minimal depth, and good approximation makes tissue adhesive an excellent option for repair. If tissue adhesive were unavailable, an absorbable suture would be appropriate to eliminate the need for return and removal of the sutures. The child life specialist was available to help you with the procedure and you closed the wound with ease.

CASE 2

For the 12-month-old girl with 2 C-shaped lacerations on her upper arm...

You explained to the medical student that inflicted bite wounds can appear as 2 separate wounds. Together, you measured the intercanine distance to be 1.5 cm. You reminded the student that adults have an intercanine distance of 2.5 to 4 cm. You further questioned the family and found they have an autistic 6-year-old son at home who often bites. Given the high infection rates of human bites, you empirically treated the patient with oral amoxicillin with clavulanate. The child life specialist was available to help you with the procedure and you closed the wound with ease.

- **Either sterile or nonsterile gloves can be used when repairing wounds.** Traditionally, sterile gloves have been the standard of care, but recent evidence has not shown any increase in rates of infection when nonsterile gloves are used.[79] Sterile gloves may still be preferred by some, as they offer a closer fit and more flexibility. Sterile gloves cost approximately $0.70 per pair versus nonsterile gloves, which cost $0.10 per pair.[79]

- **Consider using tap water for wound irrigation.** There is no evidence that using tap water to cleanse wounds increases infection rates, and there is some evidence that it may reduce infection rates.[17-19] One study estimates the annual national savings of irrigating wounds with tap water rather than normal saline to be $65,600,000.[170]

- **Consider applying a topical anesthetic at triage.** Application of topical anesthetics to simple wounds at triage can reduce total treatment time.[56]

1. **"I use topical antibiotic ointment on all the wounds I close."** Topical creams and ointments will dissolve tissue adhesives. Patients and families should be encouraged not to apply ointments over tissue adhesives.

2. **"The patient wouldn't sit still, so I called the plastic surgeon."** While specialist consultation may be appropriate depending on the wound and the family's wishes, managing anxiety and pain will be necessary whether the repair is done by a specialist or the emergency clinician.

3. **"The family said that no glass got into the wound, so I proceeded with the repair."** If the index of suspicion for a foreign body is high, the emergency clinician should proceed with appropriate imaging to evaluate whether a foreign body is present. Retained foreign bodies are a risk factor for wound infection.

4. **"The bite wound on the child's hand was small and appeared clean, so I closed it using tissue adhesive."** Tissue adhesives are not recommended for use on animal-bite repairs, stellate wounds, infected wounds, mucosal surfaces, or areas of high moisture or dense hair.[70]

5. **"I thought the hand wound was trauma from a punch. I did not consider that it might have been a fight bite."** Clenched-fist injuries occur when a closed fist strikes the teeth of another person (ie, fight bite), which can result in a hand infection. A careful history can help to determine whether there was any contact with teeth. Because 10% to 15% of human bites become infected, these patients should be given prophylactic antibiotics. Fight bites may also incur tendon injury that may not be readily apparent on initial examination.

6. **"Wound adhesives cause increased infectious complications and have a poorer cosmetic outcome compared to sutures, so I don't use them."** Randomized controlled trials have shown that wound adhesives have no increased rates of infection compared to sutures.[71,72,76] Studies have also found similar cosmetic outcomes when comparing wound adhesive to sutures.[62,66]

7. **"Use of an absorbable suture to close a wound will result in a poorer cosmetic outcome, so I always use nonabsorbable sutures."** Several studies have evaluated the cosmetic outcome and patient satisfaction with absorbable and nonabsorbable sutures and have found absorbable sutures to be no better or worse compared to nonabsorbable sutures.[63] Some studies have found that caregivers prefer absorbable sutures over nonabsorbable sutures.[64]

8. **"I give systemic antibiotics to all of my patients with traumatic lacerations."** Evidence has not shown benefit in prescribing systemic antibiotics for clean, simple lacerations.

9. **"The wound looked dirty, so I squirted some povidone-iodine in the wound to clean it."** Many antiseptics have been found to have detrimental effects on wound healing at the cellular level,[19,130,131] with no significant difference in infection rates.[132] Wounds that appear dirty or contaminated should be thoroughly irrigated to remove debris.

10. **"My patient had a simple chin laceration, so I didn't take a thorough medical history."** Obtaining a thorough past medical history can reveal conditions that may cause poor wound healing. Patients and families should be made aware that wounds may not heal as quickly or as well if there are preexisting conditions that affect wound healing.

5 Things That Will Change Your Practice

1. For wounds that may be contaminated with radiolucent objects such as wood, plastic, and organic matter, consider using soft-tissue ultrasound. Ultrasound for use of foreign body identification has been shown to be fairly sensitive and specific.

2. Anxiolysis during wound management is something that must be considered. Anxiolysis does not always have to mean administration of medication, however. Utilization of immersive virtual reality has been shown to be an effective distractive technique during laceration repair.[67] Consider utilization of similar techniques and collaboration with child life specialists if able at your institution.

3. Consider tissue adhesives for wounds that are linear and easily approximated. Studies have found no significant differences in short- and long-term cosmetic outcomes when tissue adhesives are used, as compared to standard wound closure.[70,75-78]

4. When deciding between sterile gloves versus nonsterile gloves prior to your next wound repair, remember that there have been no increase in infection rates when nonsterile gloves are used.[79,80] Use of sterile gloves is also more costly.[81]

5. In individuals with fragile skin, using sutures alone may lead to tearing through skin when under tension. Consider use of adhesive strips in addition to sutures in this situation. Adhesive strips can be placed parallel to the wound edges. The needle is then passed through the strips and skin and sutures are placed in their usual manner.

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Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of patients. Not all references are equally robust. The findings of a large, prospective, randomized, and blinded trial should carry more weight than a case report.

To help the reader judge the strength of each reference, pertinent information about the study is included in bold type following the reference, where available. In addition, the most informative references cited in this paper, as determined by the authors, are noted by an asterisk (*) next to the number of the reference.

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CME Questions

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1. **A child presents in the emergency department with a laceration on his left leg. What time interval in the history would caution you to close the wound via primary intention?**
   a. 5 hours
   b. 36 hours
   c. 15 hours
   d. 10 hours

2. **A 5-year-old boy comes in with a chin laceration that you will have to repair with sutures. You have applied LET, but after 30 minutes he still seems to have some discomfort as you lightly test the wound edges with a needle. He also appears anxious. Which of the following should NOT be your next course of action?**
   a. Ask the child life specialist for assistance
   b. Use an additional anesthetic such as 1% lidocaine with epinephrine
   c. Apply another 3 mL of LET
   d. Use a "blinder" so the child does not see the instruments

3. **Which of the following fluids is as effective as normal saline for wound irrigation?**
   a. Hydrogen peroxide
   b. Undiluted povidone-iodine
   c. Tap water
   d. Dilute sodium hypochlorite solution

4. **Which of the following irrigation methods can deliver the optimal pressure of 5 to 8 psi?**
   a. 35-mL syringe and 19-gauge needle
   b. Bulb syringe
   c. Tap water from the sink
   d. Irrigation port or cap

5. **What is the maximum dose of 1% lidocaine for a 15-kg child?**
   a. 2.5 mL
   b. 5.4 mL
   c. 6.7 mL
   d. 8.4 mL

6. **Which of the following is associated with an increased risk of wound infection?**
   a. Use of absorbable sutures for a facial laceration
   b. Use of nonsterile gloves for repair
   c. Use of an epinephrine-containing solution
   d. Use of tap water for irrigation

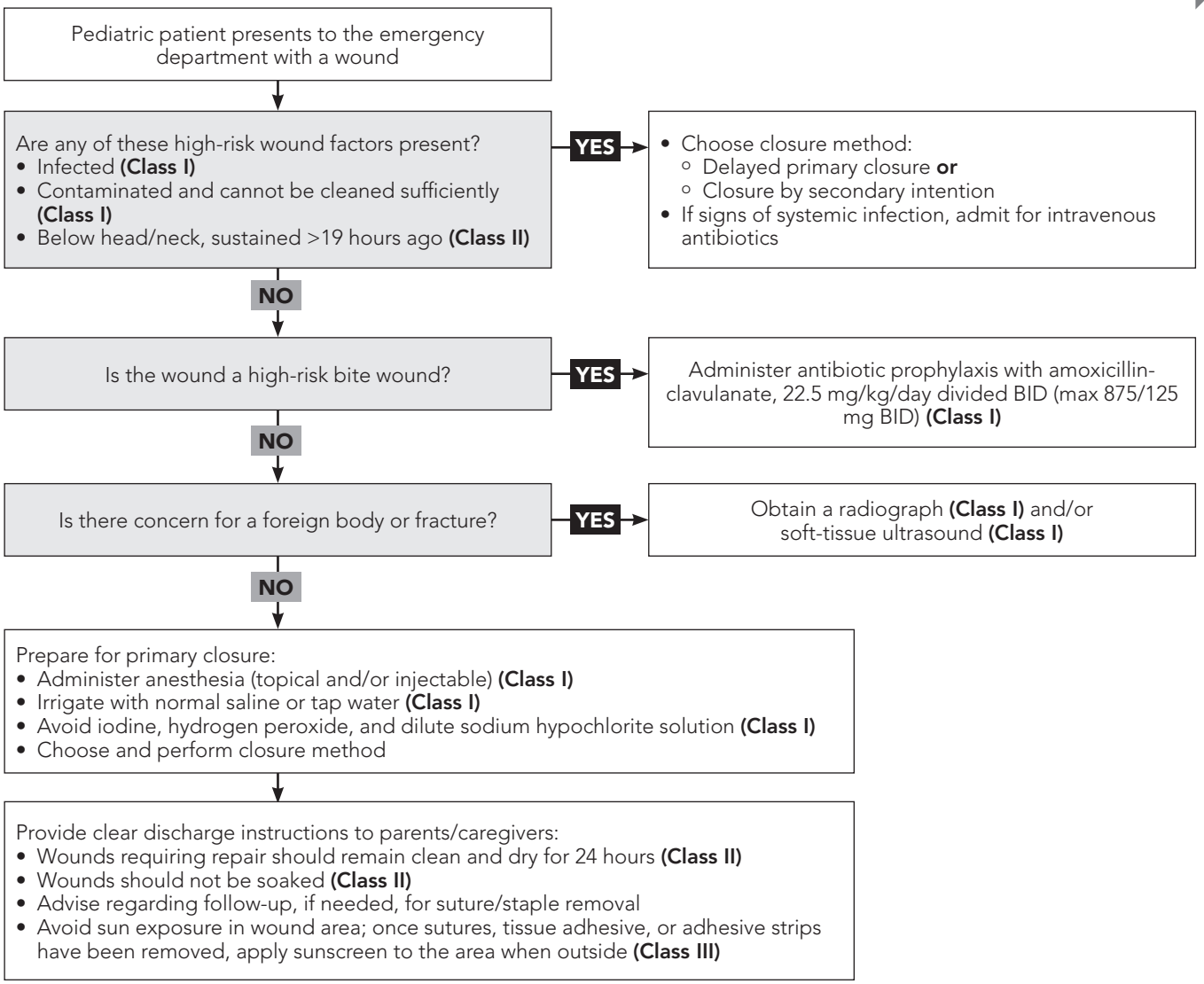
7. **You begin to close a wound on the forehead with simple interrupted sutures but notice there is a lot of tension on the wound. What should you do next?**
   a. Continue with the simple interrupted suture.
   b. Apply tissue adhesive in the wound to help close, followed by simple interrupted suture.
   c. Place a deep dermal suture.
   d. Apply adhesive strips only.

8. **What size suture would you consider placing for a superficial laceration on the sole of the foot?**
   a. 5-0
   b. 6-0
   c. 3-0
   d. 7-0

9. **What is your disposition information to a patient in whom you just placed 5-0 nylon sutures on the hand?**
   a. Return in 10 to 14 days for suture removal.
   b. Return in 7 to 10 days for suture removal.
   c. These are absorbable sutures that do not need removal.
   d. Return in 3 to 5 days for suture removal.

10. **In which of the following patients would you consider use of oral antibiotics for prophylaxis?**
   a A 12-year-old girl with diabetes mellitus who suffered a through-and-through lip laceration
   b. A fully vaccinated 13-year-old boy with obesity and a clean wound that was repaired with tissue adhesive
   c. A 14-year-old girl with unknown vaccination status and a clean wound
   d. A 5-year-old boy with a laceration on his forearm that required the use of epinephrine-containing solution

Clinical Pathway for Emergency Department Management of Wounds in Pediatric Patients



Abbreviation: BID, 2 times per day.

Class of Evidence Definitions

Each action in the clinical pathways section of *Pediatric Emergency Medicine Practice* receives a score based on the following definitions.

Class I
- Always acceptable, safe
- Definitely useful
- Proven in both efficacy and effectiveness

Level of Evidence:
- One or more large prospective studies are present (with rare exceptions)
- High-quality meta-analyses
- Study results consistently positive and compelling

Class II
- Safe, acceptable
- Probably useful

Level of Evidence:
- Generally higher levels of evidence
- Nonrandomized or retrospective studies: historic, cohort, or case control studies
- Less robust randomized controlled trials
- Results consistently positive

Class III
- May be acceptable
- Possibly useful
- Considered optional or alternative treatments

Level of Evidence:
- Generally lower or intermediate levels of evidence
- Case series, animal studies, consensus panels
- Occasionally positive results

Indeterminate
- Continuing area of research
- No recommendations until further research

Level of Evidence:
- Evidence not available
- Higher studies in progress
- Results inconsistent, contradictory
- Results not compelling

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QUICK READ

Points & Pearls

APRIL 2025 | VOLUME 27 | SUPPLEMENT 4

Pediatric Wound Care in the Emergency Department

Points

- Risk factors for poor wound healing include smoking, peripheral vascular disease, poorly controlled diabetes, steroid use, immunocompromised states, obesity, Ehlers-Danlos syndrome, cutis laxa, pseudoxanthoma elasticum, and poor nutrition.
- If there is concern for a nonradiopaque foreign body in the wound, consider soft-tissue ultrasound.
- Clean the wound with 50 mL to 100 mL of irrigation solution per cm of laceration length to clear all debris from the wound. Pressure of 5 psi to 8 psi is strong enough to overcome the adhesive forces of bacteria.
- Allow LET gel (lidocaine 4%, epinephrine/adrenaline 0.1%, and tetracaine 0.5%) to remain in place for 20 to 30 minutes. Do not use on mucous membranes or in regions where there may be vascular compromise (eg, digits, the penis, ears, or nose). Reapplication of LET after 1 dose has not shown to provide much benefit.
- To provide anesthesia to the face, consider the intraoral approach for a mental nerve block or an infraorbital nerve block.
- If available, child life specialists can help distract the child during the procedure. If necessary, oral/intranasal midazolam, IN dexmedetomidine, or inhaled nitrous oxide are effective for anxiolysis.
- Wounds on the head and neck can be closed after 19 hours, while wounds in other areas should be closed with caution after 19 hours. Shared decision making with family should always be prioritized.
- Using tissue adhesive, absorbable sutures, or adhesive strips may be more cost-effective than nonabsorbable sutures and may preclude the need for a follow-up visit.
- Absorbable sutures have been found to be noninferior to nonabsorbable sutures in the rate of wound infection, wound dehiscence, and cosmetic outcome.

Pearls

- There is no evidence that using tap water to cleanse wounds or using nonsterile gloves to repair wounds increases infection rates.
- Studies have shown that topical anesthetic preparations are equivalent or superior in analgesic efficacy compared to conventional lidocaine infiltration.
- Ideally, lidocaine with epinephrine should not be used in areas of potential vascular compromise; however, there is some evidence that it is safe to use in digital nerve blocks in healthy patients without risk for poor peripheral circulation.
- Consider a vertical or horizontal mattress suture or deep dermal suture for areas under increased tension, such as over joints.
- Consider a half-buried mattress, or corner stitch, for "V"- and "X"-shaped lacerations.
- Carefully approximate the wound margins while applying tissue adhesive, as tissue adhesive within the wound will prevent epithelialization, and foreign body reactions may occur.
- Instead of using sutures, repair scalp lacerations with staples or hair apposition, as these result in shorter wound-closure times, shorter length of procedure, and are less costly.
- Do not prescribe antibiotics for simple lacerations unless the patient is immunocompromised, the wound is contaminated, or there is an open fracture, through-and-through lip laceration, or human bite.
- Prescribe prophylactic antibiotic therapy to prevent wound infection from dog bites in patients who are immunocompromised, have advanced liver disease, have edema of the affected area, have moderate to severe injuries (especially on the hand or face), or have puncture wounds. A 3- to 5-day course of amoxicillin-clavulanate is recommended.