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Wound Care: Modern Evidence In The Treatment Of Man's Age-Old Injuries

It's just a typical Sunday morning in the ED. You look at the board, and there are 5 patients with lacerations to be cared for. A 40-year old with a finger laceration from slicing more than his morning bagel. A 65-year old with a leg laceration sustained 30 minutes ago, when he was rototilling some manure into his rose garden. A 3-year-old girl with a chin laceration from a run-in with the coffee table. A 4-year old with a tongue laceration due to a fall. And, last but not least, a 21-year-old frat boy with a forehead laceration from a fight sustained 12 hours ago.

The rotating medical student is excited and arrives armed for battle with a bulb syringe and a large bottle of povidone iodine. You shake your head knowingly and begin explaining the ***right*** *way to clean a laceration.*

MILLIONS of traumatic lacerations are treated in the United States each year. The ED is the most common arena for care of these wounds, due both to its convenience and the expertise of emergency physicians. This review covers the historical and physical exam features in evaluating a laceration and determining the most prudent course of treatment. A comprehensive approach to laceration management will be discussed. Other topics, including methods for anesthetizing and cleansing wounds and wound closure techniques, are also reviewed.

Definitions

- *Primary closure* is the closure of a wound at the time of ED presentation.
- *Delayed primary closure* is the closure of a wound 3-4 days after wounding.
- *Healing by secondary intention* is allowing a wound to heal at its natural rate, through scarring, and without attempted primary closure.

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CME Objectives

Upon completing this article, you should be able to:

1. Appropriately cleanse a wound.
2. Determine those wounds that can be closed primarily, based on time since wounding, location, and patient history.
3. Determine which type of closure technique is most appropriate for a given wound — be it suturing, stapling, taping, or gluing.
4. Understand proper uses of: delayed primary closure, topical anesthetics, and techniques for locating foreign bodies in wounds.
5. Evaluate and treat intraoral wounds.

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See "Physician CME Information" on back page.

Critical Appraisal Of The Literature

The literature review was launched with Ovid MEDLINE® and PubMed searches for articles on wound care published between 1966-2005. Keywords included laceration, wound irrigation, oral wound, wound closure, delayed wound closure, and foreign body. The articles thus obtained provided excellent background for further manual literature searches. Over 400 total articles were reviewed, and 225 of these are included here for the reader's reference. A search of the Cochrane Database of Systematic Reviews produced reviews updated in 2004 on water for wound cleansing, use of tissue adhesives, and glove and mask use in reducing infection. In addition, ACEP provided a 1999 "Clinical policy for the initial approach to patients presenting with penetrating extremity trauma," while a search of www.guidelines.gov offered no existing guidelines for lacerations or acute traumatic wound care.

The literature on historical factors predisposing to wound infection is predominantly based on surgical incision literature from the 1970s and 1980s, with a few notable recent papers. The literature basis for proper wound cleansing consists primarily of animal studies from the 1970s, with a limited number of recent studies. The use of delayed primary closure for wounds is based almost entirely on literature from the First and Second World Wars, and its subsequent application in the 1950s to the civilian sector.

The most notable areas in the recent literature deal with new techniques (eg, cyanoacrylate skin closure, topical anesthesia, and the questioning of some long-held beliefs, such as the use of sterile gloves for laceration repair) and the necessity of using sterile saline for wound irrigation.

Epidemiology/Anatomy/Pathophysiology

Epidemiology

As of 1996, 11 million traumatic wounds were seen annually in the United States.[1] The majority of lacerations occur in young adults, predominantly men.[2] The majority of wounds involve the head and neck (50%) and the upper extremity (35%).[3] The emergency physician's goal in wound care is to attain a functional closure with minimal scarring, which is achieved primarily by preventing wound infection. An observational study found the top 4 concerns of patients presenting to the ED for laceration care to be: preservation of normal function, cosmetic outcome, least painful repair, and avoidance of wound infection.[4] Cost, length of stay, and missed work were of lesser import.

All wounds presenting to the ED have a 1.1-12% risk of infection, even with proper wound care.[5] It is in defining "proper wound care" that the confusion and debate arise. A 1992 review of wound care methods by emergency physicians (64% of whom were board certified) found that many providers actually used techniques contrary to textbook and literature recommendations. Examples of this include the soaking of wounds, use of 10% povidone iodine or hydrogen peroxide, coarse scrubbing, and irrigating with low-pressure techniques.[6] Proper wound preparation and closure technique is clearly a *learned skill*, with cosmetic outcome shown to improve significantly the higher the provider's training level.[7]

Anatomy/Pathophysiology

The tissue layers involved in most traumatic lacerations are the epidermis, dermis, and subcutaneous and fascial layers. (See **Figure 1** for an illustration of the basic skin anatomy.) The skin is made up of the epidermal and dermal layers, which for standard percutaneous wound care and closure may be treated as one layer. Closures involving the dermal layer provide a wound the majority of its strength. However, the subcutaneous layer is a loose layer of adipose, nerve, and vascular structure, and closures involving the subcutaneous layer add little to wound strength. The fascial layer includes muscles, tendons, and deeper structures underlying subcutaneous fascia. Involvement of structures in and below the fascial layer makes an otherwise "simple" wound a "complex" wound, potentially requiring multilayer closure.[8]

All wounds heal by scarring — a process involving coagulation and hemostasis, inflammation, angiogenesis, collagen production, epithelialization, and wound contraction. Any medical condition that interferes with these processes (eg, diabetes, immunosuppressian, HIV) inhibits wound healing. Epithelialization, which occurs within 48 hours of wound closure, forms the watertight seal on a wound that effectively closes it from outside contamination. Subsequent collagen deposition and remodeling give wounds their strength. A wound will have 20% of its optimal tensile strength at 3 weeks, and 60% by 4 months.[9]

Prehospital and Wilderness Wound Care

There are no clinical trials evaluating the prehospital cleansing of wounds, although it makes intuitive sense that the sooner a wound is cleaned, the longer it will take bacterial counts to grow. One study of EMS personnel found that, after minimal training, they were able to accurately determine which wounds could be triaged for home care versus ED closure.[10] Existing recommendations counsel dressing most wounds in the prehospital setting.

Table 1. Historical Factors That Increase Wound Infection Risk.

Increasing patient age
Diabetes
Renal failure
Malnutrition
Obesity
Immunocompromised status
Prolonged time since wounding

The Wilderness Medical Society (http://www.wms.org) published guidelines for the wilderness care of traumatic wounds. These guidelines recommend copious irrigation (at least 500 cc) with any potable water source. Water that is made potable on site can be used for irrigation.[11] Closure is only recommended for small, clean wounds.[12]

Though similar in many respects to wilderness wounds, war wounds are highly contaminated, generally contain devitalized tissue, and should never be treated by primary closure.[13]

ED Evaluation

Initial Stabilization

Initial ED care should always focus on immediate stabilization. Lacerations and wounds are typically examined during the secondary survey and cared for after initial stabilization.

History

It is important to elicit host factors that adversely affect wound outcome. The older surgical literature identified the following risk factors for wound infection: extremes of age, diabetes mellitus, renal failure, obesity, malnutrition, immunosuppressive medication use, and history of connective tissue disorders.[14-16] In a study of wound infection in ED lacerations, Hollander et al reported risk factors that included increased age, diabetes, increasing laceration width, and obvious contamination or foreign body.[17] Patients with a combination of these risk factors are much more likely to develop wound infection. (See **Table 1** for a full list of risk factors.) In almost all studies reviewed for this article, the presence of these historical factors (ie, increased risk of wound sepsis) prevented inclusion in the various studies. Consequently, selection bias is present in a significant number of outpatient wound studies.

Each patient's immunization and allergy history should also be obtained. Patients without adequate tetanus immunization need to be brought up-to-date.[18,19] This includes giving tetanus immune globin to those patients with high-risk wounds who have not completed their initial tetanus series. (See **Table 2** on page 4 for Tetanus Prophylaxis Recommendations.) Medication allergies and latex allergies should be appropriately taken into consideration during subsequent evaluation and treatment.[20] This is particularly true of patients with allergies to local anesthetics.

Figure 1. The Skin Layers.

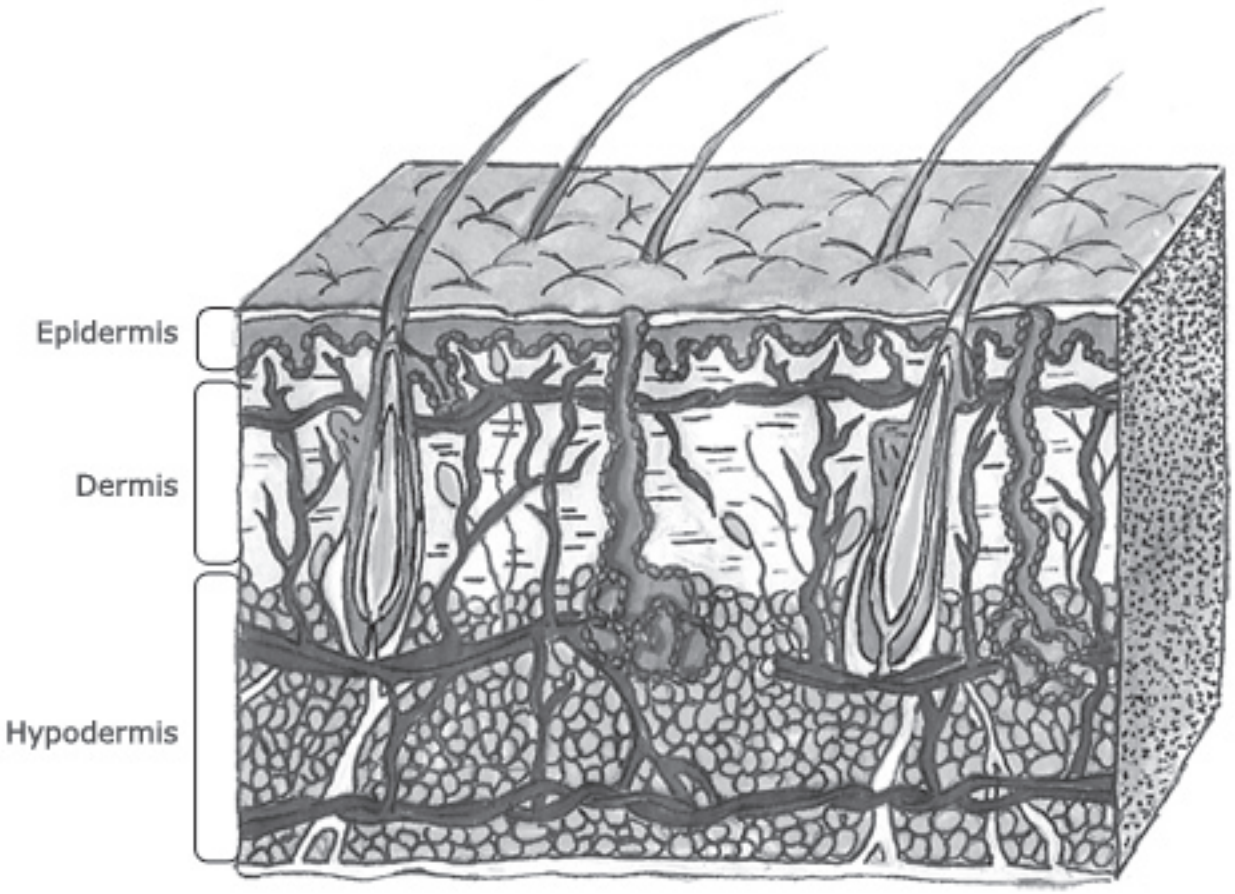


Illustration by Erin Dart

Time Since Wounding

Time from wounding is an important factor in determining if a wound should be closed primarily. The "safe" time interval from wounding that allows primary wound closure (without an increased risk of infection) is variable in the literature. The concept of a "golden period," during which time primary closure is without increased infection risk, appears to have originated with the work of Robson et al. The Robson study showed that 3-5 hours after wounding, bacteria proliferated to a level that was associated with infection.[21] This study is 30 years old and is based on burned tissue; however, these data were used by subsequent authors to support the concept of lowering wound inoculum strength to diminish wound sepsis risk.

A 1975 study by Day found no difference in infection rates between wounds presenting under 2 hours and those presenting between 2 and 4 hours.[22] A 1980 study of hand and forearm wounds by Morgan et al found significantly more infections in wounds that presented after 4 hours. The impact of the Morgan study is minimized, however, by the small sample size for wounds older than 4 hours.[23]

Several studies have found that there is an even longer period of time for "safe" closure. A study from 1980 found no difference in frequency of hand wound infections regardless of time to presentation, up to 18 hours.[24] A third-world study from Jamaica by Berk et al found no increase in wound failure closed prior to 19 hours after injury, and recommended a 19-hour cutoff time for wound closure of non-head or -scalp wounds.[25] This is an often-quoted study, but it does suffer from a follow-up rate of only 50%, as well as from its use of wound *dehiscence* rather than infection as its outcome measure. In developing a study on wound irrigation technique, Chisholm et al used a time of less than 10 hours for above-the-clavicle wounds and less than 6 hours for below-the-clavicle wounds as cutoffs for primary closure.[98] A 10-hour time frame was supported by Lammers et al in a 2003 study of 1142 wounds, where it was found that wound age over 10 hours (or over 8 hours in hand wounds) was an important risk factor for infection.[26] The ACEP clinical policy for penetrating injury of the extremity also supports an 8-12-hour cutoff for primary wound closure.[27] This clinical policy specifically references the study by Berk, which of course contains the above-noted flaws. A breakdown of the protocols used in studies reviewed for this article is shown in **Table 3**.

These combined studies suggest that up to 6-10 hours is a reasonably agreed upon "golden period" for wounds of the extremities — and up to 10-12 hours or more for the face and scalp. These time intervals, however, remain only guidelines. Evaluate each wound individually. A clean, incised facial wound without significant devitalized tissue or apparent bacterial inoculum that is 20 hours old may still be a good candidate for primary closure, while an hour-old dirty wound in a diabetic may be a poor candidate for initial closure. Clinical judgment that takes into account complex factors, such as wound age, devitalized tissue, host immune factors, retained foreign body, and apparent inoculum strength, is of great importance. If there is any doubt, the use of delayed primary closure is appropriate.

Wound Mechanism

The original animal study by Cardeny showed that blunt injuries produced stellate lacerations with an increased risk of infection compared to a shearing mechanism.[28] This effect was also described by Nylen in hand wounds.[24] Subsequent review articles and early Class III references by emergency medicine and surgical wound experts assume that the presence of devitalized tissue in traumatic wounds increases the risk of wound sepsis. Theoretically, staphylococci and streptococci, each with in vitro doubling times measured in hours, use devitalized tissue as a "culture medium."

Visible Contamination and Inoculum Strength

All wounds that present to the ED are potentially contaminated with bacteria,[29] and multiple original surgical and wound studies have demonstrated that those contaminated with more than 10^5 bacteria per gram of tissue are at high risk for infection.[30,31] However, a number of the early animal studies demonstrating the effect of inoculum strength on wound sepsis were done in burns — not incised surface wounds. Wounds that are themselves con-

Table 2. Tetanus Prophylaxis Recommendations.

Tetanus History	Clean Minor Wounds	All Other Wounds
< 3 doses in primary series*	Give tetanus toxoid only	Give toxoid and immune globin
Primary 3 Series Completed		
Last < 5 years ago	No toxoid required	No toxoid needed
Last > 5 years ago and < 10	No toxoid required	Give toxoid
Last > 10 years ago	Give toxoid	Give toxoid

*** Patients With History Of Anaphylaxis**

If patients without a complete series have a history of anaphylaxis to the Td, in most cases it is not a true allergy and the CDC would usually recommend giving Td, depending on the risk of the wound. But in cases of definite, well-documented previous anaphylaxis and a high-risk wound, these patients would need immune globin only. (According to William Atkinson [WLA2@CDC.GOV], MD, MPH, National Immunization Program, Centers for Disease Control and Prevention, e-mail communication, February 2005.)

taminated with pus, feces, or saliva probably have more than 10^5 bacteria per gram and thus, without thorough cleansing, run a high risk of infection.[31,32] Although most of the published studies on inoculum strength and wound infection are older, predominantly animal studies, it does seem that significant bacterial contamination is associated with wound infection in traumatic surface lacerations.

Extremity vs Facial Wounds

The resistance of the body to infection varies by location. Extremity wounds are more likely to become infected compared to facial wounds.[29,33] This difference in resistance is most likely due to differences in regional blood flow.[34] Tissue that is poorly oxygenated and perfused grows 10,000-fold more bacteria than well-perfused tissue.[35] Several studies have shown the highest infection risk to be in the lower extremities.[17,25,29,36] In a pediatric study by Baker, only 1.2% of lacerations developed infections, almost all of which were on the extremities. The study by Rosenberg found that infections developed in only 2% of pediatric lacerations seen, but the rate in the extremity subgroup was 8.5%.[37] A study by Lammers et al found only a 1.7-3.9% infection rate on the scalp and face, versus a 5.7-23% rate on the extremities, with thigh wounds having the highest infection rate — 23%.[26] These studies imply that highly perfused areas heal well despite higher inherent bacterial counts, and the face and scalp are at lower risk of infection.

Physical Exam

The physical examination of a wound includes assessing location, length, and depth of the wound, then determining the presence of any obvious contamination, infection, or devitalized tissue. Distal neurovascular status and functional status of structures around the wound are also ascertained. Two-point discrimination is the most accurate method for assessing sensory function in the extremities.[38] The involvement of deep structures, such as tendons, muscles, and bones, determines the need for referral and specialty consultation.

ED Management: Preparation and Cleaning

Local Anesthesia

Most wounds require anesthesia for proper evaluation and cleaning. Options include local anesthetic injections, topical anesthetics, and regional anesthesia. Local injection of anesthesia was the mainstay of wound care until recently: its major drawback remains pain of application. Techniques advocated to reduce the pain of local anesthesia include warming of the solution,[39] buffering by adding 1 cc of sodium bicarbonate to each 9 cc of lidocaine, using a small needle (eg, 30-gauge), and slow infiltration.[40,41] Injection should be performed through noncontaminated wound margins.[42] The use of buffered solution has not been found to increase the risk of wound infection (infection rate = 3.5% for lidocaine, 3.9% for buffered, $p = 0.63$).[43] Local anesthetics also carry the secondary benefit of being bactericidal.[44,45] The use of epinephrine with local anesthetics has been shown in animal studies to increase wound infection,[46-48] but no studies have been done to determine whether this occurs in humans. In general, avoid epinephrine in poorly vascularized areas, reserving its use for highly vascular areas, such as the scalp or oral cavity, where it helps control excessive bleeding. For longer duration, bupivacaine (Marcaine®) can be used, because it lasts for 4-8 hours, compared to lidocaine's 1 or 2 hours. (Both have a longer duration if epinephrine is in the solution.) Bupivacaine's pain of infiltration can also be reduced by buffering.[49]

True allergy to local anesthetics is unusual. In a large study of dental patients, in which 5018 patients received local anesthetics, only 3 had a true allergic reaction (0.06% incidence).[50] Even in the preselected subset of patients referred to an allergist for local anesthetic allergy testing, the rate was almost negligible. Berkun et al conducted a study of 236 patients referred for testing, and only 1 was positive for allergy, which was likely due to the preservative in the local anesthetic solution.[51] Numerous other studies have confirmed the extreme rarity of local anesthetic allergy, with the "true" allergy typically involving the anesthetic's preservative.[52-54]

Table 3. Time From Wounding Cutoffs For Primary Closure: The Golden Period.

Study/Year	Wound Location	Patients	Time Cutoff (In Hours)
Berk 1988	Mixed	204	< 19 hours for extremities
Chisholm 1992	Mixed	550	< 10 hours above clavicle < 6 hours below clavicle
Kanegaye 1997	Scalp	88	< 12
Barnett 1998	Mixed	163	< 12
Hollander 1998	Face/Scalp	1923	< 6
Singer 1998	Mixed	120	< 6
Beatrix 2002	Extremity	45	< 8
Lammers 2003	Mixed	1142	< 24, but rate increased at 10
Valente 2003	70% Face/Scalp	500	< 10

In those cases where a true allergy is known or believed to exist, a drug of the opposite class of local anesthetic is appropriate, which means the ester procaine should be used, instead of lidocaine or bupivacaine, which are amides. In the even rarer event of an allergy to both classes of drugs or to an unknown local anesthetic, 1% diphenhydramine injection can be used instead. It has been shown to provide equivalent local anesthesia to 1% lidocaine, though it is more painful to inject and has a slower onset of action (5 minutes versus 1-2 minutes).[55,56] Unfortunately, buffering of diphenhydramine does not appear to reduce the pain of injection.[57]

Topical Anesthesia

Topical anesthesia has become increasingly popular due to its ease of use, particularly in children, and topical anesthetics have the added advantage of not distorting local anatomy. The original topical anesthetic, TAC (tetracaine, 0.25-0.5%; adrenaline, 0.025-0.05%; cocaine, 4-11.8%), was reportedly effective for facial, scalp, and oral wounds.[58,59] The downfall of TAC was its occasional association with seizures, arrhythmias, and cardiac arrest (due to the cocaine component).[60]

LET (lidocaine, 4%; epinephrine, 0.1%; tetracaine, 0.5%) has a better safety profile than TAC and is effective for anesthesia of the face and scalp (in 75-90% of cases).[61-63] While toxicity from LET can occur if there is excessive systemic absorption of the lidocaine or tetracaine, this can be avoided by not using LET on large wounds or mucus membranes.[58] LET can be formulated in both liquid and gel forms; the latter has been shown to provide better local anesthesia and better containment to the area of care.[62] (See **Table 4** for LET Application Instructions.)

The effects of the epinephrine in topical anesthetics and its impact on wound infection rates are mixed. One study by Barker et al demonstrated that epinephrine increased infection in a guinea pig animal model. However, another study by Martin et al showed no increase in infection in their animal model.[64,65]

Examination

Once adequately anesthetized, the wound can be inspected, with particular attention paid to the presence of wound contamination, devitalized tissue, and deep structure involvement. The involvement of deep structures, such as tendons, joints, and nerves, typically makes the wound no longer suitable for closure in the ED — the involvement of extensor tendons being the one case where primary closure can still be accomplished there.[20] These complex wounds should trigger the involvement of a consultant and will often require further care in the operating room. Be meticulous in the search for foreign bodies (see next section), as they increase the risk of both wound infection as well as litigation! Once carefully examined, the wound should undergo irrigative cleansing.

Foreign Bodies

Retained foreign bodies are the fifth leading cause of malpractice claims against emergency physicians, and they have been reported to constitute as high as 24% of closed claims.[67] The most common retained foreign body by far is glass — representing over 50% of retained objects in some series.[68] Once a foreign body has been detected, a decision is then made about whether it can, or even should, be removed, as well as how or when. A deep, inert foreign body may not be worth the further risk of removal. Contaminated dirt and rock, on the other hand, should be removed, as their presence will greatly increase the risk of

Table 4. LET Application Instructions.

Use 1-3 cc of LET (works best if blood and debris are removed from wound).

Gel

- Apply to wound and wound edges with a cotton-tip applicator.
- The wound is NOT covered (as it is with solution).
- The LET is usually effective in 20 min, at which time skin around the wound appears blanched, due to the epinephrine's effects.
- The gel should be removed prior to suturing.
- LET gel anesthesia lasts about 45-60 min after it is removed from the wound.

Solution

- Paint solution onto wound and wound edges with cotton-tip applicator.
- Then apply a cotton ball saturated with LET to the wound.
- Immunocompromised status
- The LET is usually effective in 20 min, at which time skin around the wound appears blanched, due to the epinephrine's effects.

*Source: Adapted from: Kennedy RM, Luhmann JD. The "ouchless emergency department" getting closer: Advances in decreasing distresss during painful procedures in the emergency department. *Paediatr Clin North Am*. 1999;46:1215. See Reference 224.

infection. Glass located next to a neurovascular structure should be considered for removal in the operating room.[69]

The first line of defense against a retained foreign body remains meticulous examination of the wound. Nonetheless, this is not a failsafe method. A 1992 study by Avner and Baker found that, even if one could visualize the bottom of a wound, there was still a 7% chance of missing a retained glass particle that would have been noted on x-ray. For deeper wounds, such that the wound bottom could not easily be seen, the incidence of visually missed glass rose to 21%. In this study all wounds with visually "missed" glass were over 5 mm deep. Their resulting recommendation is that routine x-rays of lacerations involving glass be continued.[70]

In a medical/legal review, Kaiser et al found that failure to obtain a radiograph in the case of a retained glass foreign body resulted in an unsuccessful defense in 60% of cases. The most common reason cited for not obtaining an x-ray was the belief that glass is radiolucent. Multiple studies have found that, although there is some variation depending on how close a glass fragment lies to bone, glass is actually radiopaque in most cases. In a chicken-leg model, Courter reported that a 2-mm glass foreign body could be seen on x-ray 99% of the time, a 1-mm piece could be seen 83% of the time, and a 0.5-mm piece could be seen 61% of the time.[71] A subsequent 1999 cadaver study by Arbona found radiographs to have a 90% sensitivity for glass foreign bodies, with a 10% false-positive rate.[72] All these studies show that glass of over 2-mm dimension will be seen in almost all cases. In addition, these studies, which were conducted with glass of varying lead content, have not shown that the lead content makes any significant difference in the detection size of the glass. Therefore, plain radiographs are the initial study of choice for either metal or glass foreign bodies.[71]

Greater problems occur with wood and plastic foreign bodies that do not appear on x-ray. Wood splinters, particularly of redwoods and cedars, are very reactive and can lead to chronic pain and inflammation if not removed.[73,74] Fortunately, these foreign bodies do appear on both CT scan and MRI,[75,76] although CT is less effective in detecting wood objects more than 48 hours after wounding, because wood takes up water and converts to a density equivalent to soft tissue.[77]

Ultrasound has been used successfully to localize vegetative foreign bodies.[78-80] In 2 studies, high-resolution US has been shown to have a sensitivity of 95-98% and a specificity of 89-98% in detecting predominantly nonradiopaque foreign bodies that were 1 x 2 mm or larger.[81,82]

Removal

Once a foreign body is discovered, the decision must be made about whether and how it should be removed. (See **Table 5**.) Highly reactive objects, such as vegetative material and wood, as well as contaminated objects and clothing, should be removed.[83] Foreign bodies that impinge on neurovascular structures or joints, or that otherwise restrict mechanical function, should also be removed. The latter case would include foreign bodies in the foot, which almost always inhibit gait by pain with weight bearing.[84] Small, inert foreign bodies that are not easily reached and not near a vital structure can be left in place.[69,84]

Wound Irrigation

Irrigation has been used for wound care since 2200 BC and remains a fundamental of treatment.[85] Irrigation fluids remove bacteria and contamination from a wound. At the same time it is vital to avoid introducing toxic or inflammatory materials into the wound that can reduce resistance to infection. Perhaps the most common-sense statement regarding irrigation fluid is summed up as follows: "It is desirable never to put anything in the wound that cannot be tolerated comfortably in the conjunctival sac."[86]

Much of the research on wound irrigation has been done in animals, where the measured outcomes have included both direct (wound infection) and indirect (quantitative bacteriology) measures. The standard technique for wound irrigation is high-pressure irrigation (15-25 psi), which has been shown in numerous studies to remove small particulate matter and bacteria *without* disseminating infection through tissue planes.[87-90] In 1975, Rodeheaver demonstrated that irrigation at 15 psi removed 85% of bacterial contamination from a wound, whereas low pressure (1 psi) removed only 49%.[89] "High-pressure" irrigation is most often accomplished by using a 30-60-cc syringe to push fluid through a 19-gauge catheter with maximal hand pressure. This technique generates peak exit pressures of 27-31 psi and trough pressures of 11-17 psi, with slightly lower pressures in the wound (around 8 psi).[91] A commonly used but *ineffective* technique is piercing an IV bag with a needle, then squeezing it with maximal hand pressure, thereby generating a stream of irrigation fluid. At best this technique generates a maximum pressure of only 4 psi, with even lower impact pressures in the wound. These results have also been seen in animal studies, where high-pressure but not low-pressure (bulb syringe) irrigation significantly reduced bacterial contamination of wounds.[92] An ED-based, randomized study by Longmire et al showed a statistically significant reduction in both inflammation and infection in wounds cleaned with syringe and needle lavage, compared to bulb syringe cleansing. Syringe and needle lavage cleaning reduced inflammation and infection from 27.8% and 6.9% to 16.8%

Table 5. Indications For Foreign Body Removal.

Reactive materials, such as wood and vegetative material
Contaminated material
Clothing (should *always* be considered contaminated)
Most foreign bodies in the foot
Impingement on neurovascular structures
Impairment of function
Easy to remove and without risk of complication

and 1.3%, respectively.[93] Wounds should therefore be irrigated with the syringe and catheter technique, or with devices that provide similar irrigation pressures.[94]

Irrigation Volume

There have been no well-designed studies addressing the optimum volume of fluid for irrigation: most studies use a minimum of 250 cc of irrigant. Only 1 reference uses a number, 60 cc/cm of wound, but this has not been corroborated.[26] One animal study comparing high-volume, low-pressure (1.6 psi) to standard-volume, high-pressure (5-8 psi) irrigation found the low-pressure method to be as effective in removing bacteria. With the low-pressure technique, 2-3 times as much volume was used as in the high-pressure technique.[95] One can conclude from the present research that high-pressure irrigation remains the "gold standard," and that there may be an advantage to large volumes of irrigant, as well.

Irrigation Fluid

Sterile saline solution is the most commonly used wound irrigation solution.[3,96,98] The only recent item in the literature for improvement in its use is a study that recommends warming the solution prior to its use as an irrigant.[97] Pressurized containers of saline for irrigation have been developed to speed irrigation times. Use of this technique has been found to be nearly twice as fast as traditional syringe and catheter irrigation, and results in no significant increase in wound infection rate.[98]

Povidone-Iodine Solution (Betadine®)

Numerous other solutions have been tried for wound irrigation, one of particular interest being povidone iodine. Standard povidone-iodine solution (10%) is tissue toxic, particularly to fibroblasts in animal studies, and it has not been shown to reduce the incidence of infection; therefore, do not use povidone iodine at this concentration.[99-102]

A prospective comparison of irrigation with dilute (1%) povidone iodine and scrubbing with the same was found to reduce wound infections in one study of human subjects.[103] This is in fact one of the few studies to show a statistical advantage to using dilute povidone-iodine solution. This randomized, prospective study was flawed by having 20% of participants lost completely to follow-up, as well as 35% of the remainder having follow-up only by phone, a technique known to be flawed in determining wound infections.[104] An animal study by Howell et al showed 1% povidone-iodine irrigation to significantly reduce the bacterial count of streptococcal-inoculated wounds, but not those inoculated with Staphylococcus.[105] This study also showed no benefit from gently scrubbing the wound with poloxamer 188 prior to iodine irrigation. Other studies have been performed that show little toxicity from 1% Betadine® (which is made by diluting standard 10% povidone-iodine solution by 1:10).[106,107] The use of 1% Betadine® for wound irrigation therefore remains indeterminate; it does not appear to worsen outcome, but has very limited supporting evidence for any advantages over the simpler use of water or saline.

Other Irrigants

Hydrogen peroxide is tissue toxic and poorly bactericidal, and as such has "no role as a wound irrigant."[108-112] Detergents have likewise proven tissue toxic in animal studies.[113,114] Antibiotic solutions, such as bacitracin, have not been shown to reduce the incidence of standard wound infection. There have, however, been several case reports of anaphylaxis induced by intraoperative irrigation with bacitracin solutions.[115,116]

Tap water has been studied, due to its low cost and immediate availability. Animal studies have shown that tap water is as effective as sterile saline in reducing wound infection and bacterial counts.[117] One Australian and two European studies have shown tap water to be as effective as sterile saline.[118-120] Two more recent studies also support this practice. Bansal, in a small double-blind study comparing tap water to sterile saline, found no significant difference in wound infection rates.[121] In this study lacerations were all simple, less than 8 hours old, and irrigated with 500 cc of solution at high pressure; hand lacerations were excluded. A larger subsequent prospective study of 500 pediatric patients with simple lacerations less than 8 hours old found no difference in wound infection rates, despite a higher number of hand wounds in the tap-water group. The tap-water group did receive a significantly larger volume of irrigation fluid.[122] The Cochrane review database has stated that, although evidence is limited, there is no difference in wound infection rates with the use of tap water as an irrigation fluid, provided the water is potable.[123] Given the lack of clear advantages to any other irrigation solution, saline and tap water continue to be the irrigation fluids of choice for wound care.

Debridement

Debridement is an age-old technique with little recent research, due to its universal acceptance in wound care; nonetheless, debridement has been studied in a guinea pig model, where it was shown that wounds closed with devitalized fat, skin, or muscle resulted in a high incidence of infection.[124] In performing debridement, one must always consider the balance of tissue loss versus function. If there is any question concerning a tissue's viability, it may be better to minimize the debridement and opt for delayed primary closure. Using delayed primary closure will allow one to determine the full extent of devitalized versus viable tissue, with little increased risk of wound infection. As part of debridement, all obvious debris and necrotic tissue should be removed from the wound.

Skin and Hair Preparation

Skin preparation is done to reduce the quantity of bacteria on the surface of the skin through which sutures or other closure techniques are to pass. It has been suggested that hair is a source of bacterial contamination.[125] Shaving the hair does make closure easier by preventing hair from becoming trapped in the wound. Unfortunately, shaving also causes an increased risk of wound infection by inducing trauma to the skin around the wound. Seropian and Reynolds showed that infection risk increased from 0.6%

to 5.6% when hair was shaved from a wound, rather than being removed by a depilatory agent.[126] The prospective study of surgical wounds by Cruse supports this, as well. In the latter study, the infection rate went from 0.9% with no shaving to 2.4% with shaving.[3] The use of clippers, on the other hand, is not associated with any such increased risk of infection, so if hair removal is required, clipping is the recommended technique.[127]

The use of skin disinfection agents (such as povidone iodine) around a wound is less clear, even though povidone iodine certainly helps disinfect the skin and is a standard in the operating room. The Cochrane review found there was insufficient research to draw meaningful conclusions regarding the use of antiseptic solutions around traumatic surface wounds before closure.[128] If the choice is made to use them, one must assiduously avoid instilling any 10% povidone iodine into the wound.

Antibiotic Use

Incised, clean, early traumatic wounds in non-immune-compromised hosts do not require prophylactic antibiotics. Studies from the '70s up to the present time show no benefit to the use of antibiotics in these injuries.[29,32,36,129-132] A meta-analysis of prophylaxis studies by Cummings and Del Beccaro found no support for the routine use of prophylactic antibiotics in simple lacerations. In fact, they found a slightly higher incidence of infection in patients treated with non-penicillinase-resistant antibiotics — 1.16 with non-penicillinase antibiotics, 1.0 with penicillinase-resistant antibiotics).[5] Indications for the routine use of antibiotics in lacerations are quite limited. Antibiotics have been advocated for patients with prosthetic devices or those at risk of developing endocarditis.[27,29,133] There has been a case report of endocarditis developing after an infected scalp laceration.[134] The single reliable study showing an advantage to prophylactic oral antibiotic use was an evaluation of penicillin for intraoral wounds. The findings of this study and their significance will be discussed in more detail later further on in this article.

Wounds that are obviously infected do require antibiotics. Also, contaminated wounds that are closed primarily may receive antibiotics, although this practice is based on consensus. Lymphedematous patients, in addition, are believed to benefit from prophylaxis.[135] (See **Table 6**.)

Drain Placement

The placement of surgical drains (eg, Penrose drains) has been shown by Magee et al to increase infection rates.[136] This one animal study suggests that drains should not be used, though the practice has not been studied in humans with traumatic lacerations.

Closure Technique

Traditional medical teaching and CDC guidelines recommend the use of sterile technique during laceration repair,[137] although this position has been questioned, because there is no supporting literature.[138] A study by Ruthman et al showed that closure of lacerations by providers without caps and masks did not lead to an increased incidence of wound infection,[139] and a study by Bodiwala showed that laceration closure with the provider wearing no gloves did not increase the rate of infection compared to the use of sterile gloves.[140] Still, at a minimum, gloves of some kind are recommended to protect the operator. An initial study by Worral of sterile versus nonsterile gloves found no difference in wound infection rates.[141] This study was underpowered and not randomized, but a well done, randomized study by Perelman found the same results.[142] The suggestion is that nonsterile gloves, which provide "universal precaution" protection to patient and provider, may be appropriate for laceration care.

Whatever type of glove is chosen, "dusted gloves" *must* be avoided. While their popularity is on the wane, many surgical gloves still contain dusting powders to facilitate putting them on. In an animal study these powders were shown to increase the incidence of wound infection.[143]

Latex gloves should also be avoided, for obvious reasons, in those patients allergic to latex.

Table 6. Indications For Prophylactic Antibiotics.

Indication	Level of Evidence
Presence of prosthetic device(s)	Class III
Patients in need of endocarditis prophylaxis	Class III
Open joint or fractures associated with wound	Class I
Human, dog, and cat bites	Class II
Intraoral lacerations	Class II
Immunocompromised patients	Class III
Heavily contaminated wounds (eg, feces, etc)	Class III

Closure Methods

Sutures

The standard for wound closure over thousands of years has remained the placement of sutures. Proper suture material and suturing technique are based on the type of wound, its location, mechanical stress, and the infection risk.[3,14] Percutaneous sutures are used for low- to medium-tension wounds.[14] Nonabsorbable suture material is the standard for percutaneous use, because nylon and polypropylene are low reactive materials with good tensile strength.[14,144,145] Natural fibers (eg, silk or cotton) are more reactive than synthetic fibers, have a higher incidence of wound infection in contaminated wounds, and should be avoided in most cases.

Dermal sutures are placed to reduce wound tension, aid closure, reduce wound dead space, and reduce hematoma formation.[14] Use absorbable suture material for dermal stitches. All absorbable sutures are more reactive than nonabsorbable sutures, with natural absorbable suture being the most reactive.[144] Synthetic absorbable suture material is preferred for most dermal closures. Dermal sutures have been shown in animal studies (of *contaminated wounds*) to increase the risk of infection.[146,147] This result

also was seen in one human study published in 1956.[148]

The placement of dermal sutures has not been shown to increase infection in *clean wounds*.[149] A study of 114 high-risk vascular surgery patients found no difference in groin wound infection rate regardless of closure with subcuticular vs simple sutures and running sutures vs staples.[150] A secondary data analysis by Singer et al of data collected on multiple closure types also did not find an increase in infection with the use of dermal sutures.[151] Sutures placed in the subcutaneous adipose tissue (under the dermal layer) fail to reduce wound tension and increase the infection rate, and thus should not be placed.[152]

Closing dead space in a wound is controversial. Old animal studies have shown that the use of dermal sutures to close dead space in contaminated models leads to increased infection compared to leaving the dead space alone.[153] This has not been shown to be the case, however, in clean wounds.

The use of interrupted versus other types of sutures has no effect on infection rate.[154]

The suture size for a particular area should be the smallest that can resist the wound tension. (See **Table 7** for more information on suture selection.) Improved cosmesis will result from using the smallest amount of suture material possible. Wounds subject to high tension should be closed with larger diameter suture material.

Glue

Octyl cyanoacrylate adhesive received FDA approval in 1998 under the brand name Dermabond®. Dermabond® forms a plastic adhesive bond on initial application and approaches 50% of the strength of 5-0 suture material. Numerous studies and a Cochrane review support the closure of simple lacerations with cyanoacrylates, leading to comparable cosmetic outcomes compared to standard suturing.[155-159] Two recent meta-analyses supported cyanoacrylate use and found that wounds closed with tissue adhesives were not significantly different from sutured wounds in terms of cosmesis. Tissue glue is placed more quickly than stitches (5.7 minutes quicker on average) and has the added advantage of being less painful.[160] The meta-analysis did find an increased rate of dehiscence for glued wounds (compared to suture closure) that was small but statistically significant. In this publication the number needed to harm (NNH) was 25 patients; this was balanced by a significant decrease in wound erythema favoring the use of adhesive (NNH: 8).

Physicians should consider cyanoacrylates for non-mucosal facial and low-tension extremity wounds (ie, wounds not located over joints) that would require a 5-0 or smaller suture. A study of cyanoacrylates for closure of high-tension excisional wounds found tissue glue to be cosmetically inferior to sutures in this type of wound.[161] This study was underpowered (n = 42) and not randomized. A 2002 prospective study of tissue glue vs subcuticular sutures for closure of herniotomies found there to be no difference in cosmesis or wound complications.[162] A study (also on herniotomy patients) by Switzer et al, however, found tissue glue to be significantly more likely to have wound complications, as well as to trend toward worse cosmesis.[163] A study using histoacryl blue, the isobutyl predecessor of Dermabond®, interestingly found no difference in cosmetic outcome when glue was used on facial wounds, regardless of whether the laceration went with or against Langer's lines.[164] Other studies have also shown cyanoacrylates to be either bacteriostatic or bactericidal.[165-167]

A 1995 study performed in Canada compared the cost of tissue adhesive to suturing pediatric facial lacerations, and found that tissue adhesives were more economical than sutured wound closures. Even if absorbable sutures (thus requiring no return visit for suture removal) were used, suturing was 2.3 times more expensive than adhesive. If nonabsorbable sutures were used, suturing was 6.8 times more costly than ahdesive.[168,169] One problem with cyanoacrylates is their tendency to seep into unwanted areas. The advent of high viscosity octylcyanoacrylate addresses this problem.[170] If cyanoacrylates get into undesirable areas (such as, most commonly, the eye/eyelid of a child with a forehead laceration being closed), the glue can be removed with a petroleum-based product (eg, ophthalmic bacitracin, erythromycin ointment, or mineral oil).

Cyanoacrylates are effective for use anywhere one would normally use a 5-0 suture. Being able to care for a child's laceration without needles may be the best wound care advance in decades.

Staples

Staples are one of the fastest methods of wound closure.[171,172] They also have low wound reactivity and low wound infection rates.[173-175] Two recent studies found that stapling is significantly faster than suturing, causes no increased wound complications, and is less expensive than suturing.[176,177] The risk of needle sticks is also reduced with the use of staples. Compared to suturing on the scalp, stapling has been shown to have no difference in cosmetic outcome.[178] This comparable cosmetic outcome may not hold, however, in those who scar easily, particularly if staples are left in place for a prolonged period.[179] Staples have been recommended for use on scalp, trunk, and extremity wounds;[20] concerns about facial cosmesis preclude their use in this area. Staples also should not be used in anyone foreseen to need an MRI, and possibly a

Table 7. Suture Selection.

Face	5-0 to 6-0
Scalp	3-0 to 5-0
Chest	3-0 to 4-0
Back	3-0 to 4-0
Abdomen	3-0 to 4-0
Extremities	4-0 to 5-0
Joints	3-0 to 4-0
Oral	3-0 to 5-0 *absorbable*

CT, because staples can cause scatter artifacts on CT.[180]

Surgical Tapes

Surgical tapes (ie, Steri-Strips™) are the least reactive of all closure techniques,[181] though they frequently require the use of tissue adhesive aids, such as tincture of benzoin, which are themselves reactive and can increase the risk of wound infection.[182] Surgical tapes have the lowest tensile strength of any wound closure device and thus the highest failure rates.[183] They should be avoided, for obvious reasons, in hairy areas, and they also lose significant holding ability when wet.[14] In a 2004 study on simple, low-tension pediatric facial wounds, Steri-Strips™ resulted in a cosmetically equivalent wound closure compared to cyanoacrylate (ie, tissue glue) closure.[184]

"Hair" Closure in Scalp Wounds

Hair apposition and tying techniques have been advocated for the closure of simple scalp wounds. A 1981 technique in pediatrics involves twisting hair on either side of the wound and tying the twists together to pull together and close the wound. Tincture of benzoin was added to the hair knot to prevent slippage.[185] A modification of the technique by Davies used Nobecutane spray to seal the knot.[186] Both techniques require cutting and removing the knot several days later, when the wound is closed.

One novel approach involves twisting together hair from both sides of the wound and applying cyanoacrylate directly to the twisted hair to keep it together. This technique avoids the requirement of cutting the knot, as the hair will come apart on its own as the cyanoacrylate wears off. This technique was limited to patients with lacerations 10 cm or less in length and hair longer than 3 cm. With 96 patients in the study group and 93 controls, there were no significant differences found in wound healing, scarring, or wound breakdown, but there were significantly lower pain scores and procedure times compared to suture closure.[187] A review by Singer noted that the mean laceration size was only 3 cm, the technique resulted in apposition of only the outermost skin layers, and provided no hemostasis to the wound.[188] For those wounds meeting the criteria outlined above, this is a simple, effective technique.

Delayed Primary Closure (DPC)

Despite its long history of use in contaminated wounds, and its descriptions in the medical literature since 1919, delayed primary closure remains a much underused method of wound care. In one of the first studies of this technique, DPC reduced the infection rate by 50% in 104 extremity wounds.[189,190] Two reviews in the surgical literature recommend DPC for heavily contaminated wounds (eg, war wounds), which even after proper cleansing have a high incidence of infection, if closed primarily.[191,192] Although not prospectively studied, DPC is a recommended technique for contaminated wounds that present to the ED.[193] DPC has been well studied for contaminated surgical and war wounds,[194,195] where it clearly decreases wound infection rate.[196] In a limited observational study, Shepard found an infection rate of only 3% in 101 high-risk wounds treated by delayed primary closure.[197]

Delayed Primary Closure Technique

Begin by cleaning and debriding the wound as described above. Separate the wound edges with fine mesh gauze to allow drainage, and apply a bulky gauze dressing over this to prevent further contamination. The dressing can remain in place until rechecked in 3 or 4 days, at which time the wound can be closed — *if* no infection exists — following repeat wound cleansing and debridement.[193] The wound should be examined earlier, if increased pain, drainage, or fever is noted, at which time it is recleaned and dressed. A more aggressive approach, useful for particularly "dirty" wounds, is to examine and cleanse the wound daily, until it appears to be clean and healing without signs of infection (again, typically, at 3-5 days), at which time it can be closed.[198]

Secondary Intention

"Secondary intention" refers to allowing a wound to heal without formal closure. In this process, a scar first forms to close the wound, then contracts to reduce the ultimate wound size. The primary advantage to this technique is its simplicity; the disadvantage is the associated delay in wound closure and increased scar size. This may be a viable technique, however, for small wounds. Quinn et al

Continued on page 13

Cost- And Time-Effective Strategies For Wound Care

1. Staples and cyanoacrylates are the quickest closure methods.

2. Small, simple hand lacerations (< 2 cm) do not require primary closure.

3. Sterile gloves have no advantage over nonsterile gloves in reducing wound infection.

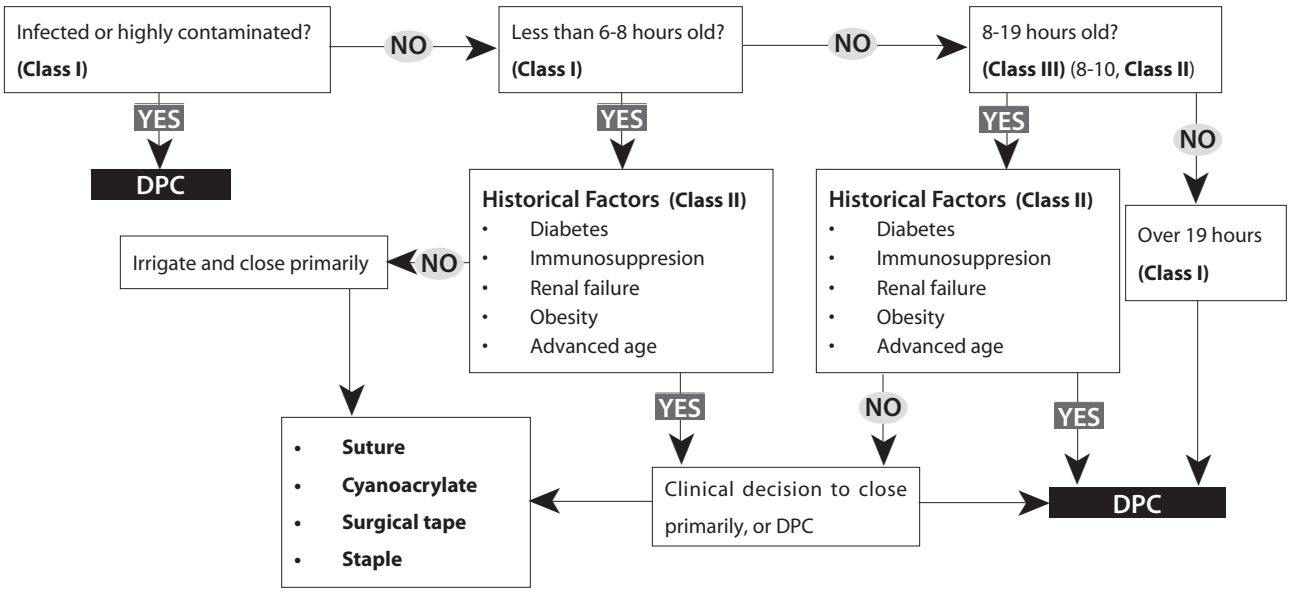
4. Clean tap water is as effective as (and cheaper than!) sterile saline for wound irrigation.

5. Cyanoacrylates or absorbable sutures are cost-effective for patients, as they do not require return visits.

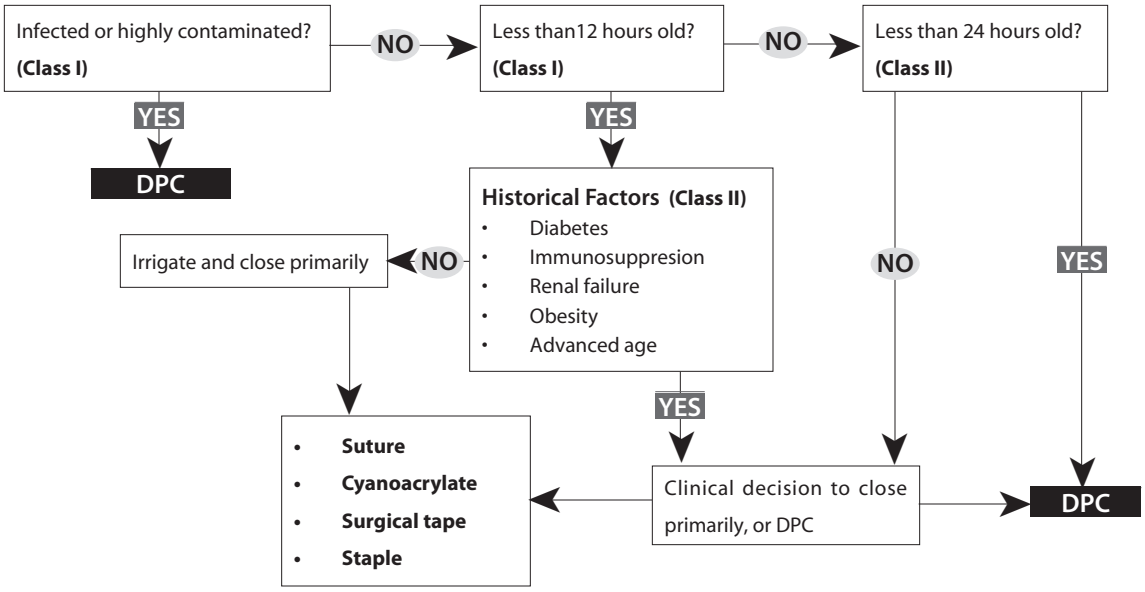
6. Application of LET in triage allows a wound to be anesthetized by the time you see the patient. ▲

Clinical Pathway: Management Of Common Lacerations

Extremity/Trunk Lacerations



Head/Face/Scalp Lacerations



The **evidence for recommendations** is graded using the following scale. For complete definitions, see back page. **Class I:** Definitely recommended. Definitive, excellent evidence provides support. **Class II:** Acceptable and useful. Good evidence provides support. **Class III:** May be acceptable, possibly useful. Fair-to-good evidence provides support. **Indeterminate:** Continuing area of research.

This clinical pathway is intended to supplement, rather than substitute for, professional judgment and may be changed depending upon a patient's individual needs. Failure to comply with this pathway does not represent a breach of the standard of care.

Continued from page 11

in 2002 showed that conservative management (ie, healing by secondary intention) resulted in no cosmetic or functional difference compared to primary closure in selected hand lacerations. The lacerations were uncomplicated (no deep structure/tendon/joint/nerve involvement), less than 2 cm in length, and located distal to the distal volar wrist crease. All wounds were irrigated with tap water and then, based on randomization, were either closed with sutures (4-0 or 5-0) and dressed, or dressed without suturing. Those treated conservatively had significantly less pain and a quicker ED discharge time. At 3 months there were no differences in cosmetic outcome or time of return to hand function. One sutured wound became infected, and no conservatively treated wounds became infected (not significant).[199] Suturing may not offer any advantages over conservative treatment of small hand lacerations.

Wound Aftercare

Wound dressings have been in use for thousands of years. Of course, all wounds form the natural dressing of a scab. Unfortunately, scab formation, while it does protect the wound from the external environment, has been shown in animal studies to slow epithelialization and trap bacteria in the wound surface.[200] In most cases a dressing that maintains a warm, moist environment has been shown to aid healing.[201] For incisional wounds, a dressing that protects the wound from foreign material and absorbs exudates is desirable for ideal wound epithelialization.[202] Dressings have their greatest utility from the time of repair until epithelialization is complete; they are best used for the first 3-4 days.[225]

Topical Antibiotics

Antibiotic ointments have been used as both a form of simple dressing and a method of reducing wound infection. In a prospective study by Dire et al, triple antibiotic ointment reduced the incidence of postclosure infection compared to a petroleum jelly control (4.5-5.5% for bacitracin and Neosporin® vs 17.6% for petroleum control).[203] This advantage was not reproduced in a similar study of ambulatory surgical patients, where no differences in infection rates were found between groups.[204] Since these 2 studies identify no downside to antibiotic ointments, their use is recommended. Antibiotic ointments and petroleum jelly are contraindicated, however, when cyanoacrylates are used, because ointments and petroleum dissolve tissue glue.

Sun Exposure

Permanent hyperpigmentation can occur if a wound is exposed to excess sunlight during the roughly 6-month period after closure. To prevent this, some clinicians recommend sunscreen on the wound during this time frame. This recommendation is based on changes noted after dermabrasion, but is otherwise poorly studied.[205]

Suture and Staple Removal

Sutures or staples on most areas of the body should be removed after 7 days. Facial sutures should be removed within 3 to 5 days for best cosmesis.[3,14] Stitches subject to large tension forces (eg, over joints) should remain in for 10 to 14 days.[3,144] Suture track mark scars tend to occur if sutures are left on the face for more than 5 days, and on the rest of the body for more than 7 days.[206] See **Table 8** for recommended suture and staple removal times.

Special Circumstances

Wounds involving burns, certain types of bites, and intraoral lacerations require special consideration. Previous issues of this publication have already been devoted to the two former topics. (See *Emergency Medicine PRACTICE*, Thermal Burns: Rapid Assessment And Treatment, September 2000, and *Emergency Medicine PRACTICE*, Dog, Cat, And Human Bites: Providing Safe And Cost-Effective Treatment In The ED, August 2003, for more information.) The special-case wounds that have not yet been given in-depth coverage are oral lacerations, which do involve specific care techniques and considerations.

Mouth/Oral Wounds

The mouth and associated structures are highly vascular and therefore tend to heal more quickly than other areas of the body. Because of its extensive blood supply, even small tissue avulsions in the mouth tend to survive. Debridement should therefore tend to favor tissue salvage rather than removal in the oral cavity. The basic approach to oral wounds is the same as for all other wounds — a good examination with attention to possible foreign bodies, such as teeth, followed by thorough wound irrigation. There have been no studies that define a "golden period" for closure of intraoral wounds. In a tongue laceration study by Lamell, mean delay from injury to treatment was 4.5 +/- 9.0 hours (see below).

Buccal Mucosa

Lacerations of the buccal mucosa and oral gingiva heal without repair, provided the wounds are not large and gaping. Large wounds (greater than 2 cm) do tend to trap food and should be repaired. Mucosal lacerations that end up between the chewing surfaces of the teeth also require repair. Otherwise, for small lacerations (2 cm or less), clo-

Table 8. Suture And Staple Recommended Removal Times.

Location	Time (In Days)
Face	3-5
Scalp	5-7
Extremity (low-tension)	6-10
Extremity (high-tension)	10-14
Abdomen	6-12
Chest and Back	6-12

sure is not necessary.[207] Through-and-through lacerations should have the layers closed from the inside out, with the caveat that irrigation may be repeated after the inner mucosal layer is closed. Anatomic structures of concern in facial buccal lacerations are the parotid gland and Stensen's duct. To test for ductile integrity, the inside of the buccal mucosa is dried, then the parotid is pressed; saliva will appear at the duct's opening, if it is intact. A lacerated duct should be referred to an ENT or oral surgeon for repair.[208] A laceration over the gland itself (with an intact duct) is repaired by simply closing the skin over the gland.

Tongue Lacerations

The literature is variable on whether tongue lacerations should be closed. Some suggest that all tongue lacerations be repaired to prevent continued bleeding. In other cases the recommendation is to repair only large gaping or flap lacerations. Several textbooks on oral and dental trauma have different recommendations, ranging from suturing almost all wounds,[209] to never suturing any, since suturing can lead to invasive closed space infections.[210] Still others recommend only suturing wounds larger than 2 cm or when bleeding control is at issue.[211] The only consensus is on lacerations that bisect the tongue, in which case all agree that these should be closed to prevent healing that results in a reptilian, "serpent tongue" appearance.[207-209]

There are limited studies on tongue lacerations. A pediatric study of 28 patients found no difference in the quality of result or posttrauma morbidity between those lacerations that were sutured and those that were not. There was also no significant relationship found between laceration size or presence of bleeding on initial presentation and outcome.[212] The children in this study were triaged to see if they met preestablished criteria for suturing (eg, through-and-through wounds, gaping wounds with tongue at rest), so it was not a strictly randomized study. Also, two of the tongues lost their sutures within 48 hours. Nonetheless, despite this study being somewhat limited

Eleven Pitfalls To Avoid

1. Failing to irrigate with the proper technique.
Proper irrigation requires a wound impact pressure of around 8 psi. This is accomplished with a syringe and catheter technique or the equivalent. Don't allow your technicians or lower-level providers to use a bulb syringe or "needle hole in IV bag" technique.

2. Failure to consider delayed primary closure.
If a wound is dirty and contaminated, it will become infected, even if you clean it well. Use delayed primary closure on all heavily contaminated wounds. The patient will need to come back for closure, but that's easier than being admitted for a wound infection and having a poor cosmetic outcome.

3. Using cyanoacrylates on high-tension areas.
Skin glue is designed for areas of low tension where a 5-0 suture would be used. It has a tendency to fail, allowing the wound to dehisce in high-tension areas. Either place a dermal suture to reduce the tension, or don't use glue.

4. Using improper aftercare dressings.
Bacitracin reduces the infection rate in sutured wounds, but it should not be used on a cyanoacrylate-closed wound. It will dissolve the glue and dehisce the wound.

5. Using antibiotics to make up for poor wound cleaning.
Prophylactic antibiotics are of little use in most wounds. Failure to properly clean the wound is what leads to infection, not failure to use antibiotics.

6. Failure to use clinical judgment when considering "golden periods" for wound closure.
A child with a clean facial laceration will likely do well with primary closure, even if he presents 22 hours after sustaining it. On the other hand, a diabetic with lupus who sustains a clean cut to their hand and presents 30 minutes later should probably still be closed by delayed primary closure.

7. Failure to find a foreign body.
A retained foreign body is not only a frequent cause of malpractice lawsuits, but it magnifies manyfold the risk of wound infection and bad outcomes. Thoroughly examine every wound and, if it is around a joint, put it through a full range of motion. If your exam turns up no foreign body, but the history suggests it, get a radiographic study. Use US, CT, or MRI to look for wood, plastic, or vegetable matter.

8. Using povidone iodine or other irrigation solutions to clean wounds.
The standard for irrigation is sterile saline, though potable tap water appears to be just as effective. If povidone iodine is used, it should be diluted to 1% — anything stronger is tissue-toxic and can actually increase the incidence of wound infection. Most other irrigation solutions are either of no benefit or worse (ie, tissue-toxic).

9. Failure to warn patients of infection risk and scarring.
All wounds have a risk of infection, even with proper care, so let your patients know this and explain what you have done to minimize the risk. All wounds heal by scarring, therefore you should not tell your patient there will be no scar; rather, explain what you have done to minimize its size, but reiterate that there will also be at least a minimal scar.

10. Failure to align the vermillion border in lip lacerations.
A misalignment of more than 1 mm can make a lip scar very obvious to the viewer. Take meticulous care in alignment of the vermillion border in lip lacerations.

11. Failure to suture a bisecting, anterior tongue laceration.
One tongue laceration that *always* requires repair is an anterior, "bisecting" laceration. Failure to suture this wound can result in a scar in the form of a "reptilian tongue." ▲

by lack of randomization, it suggests no improvement in outcome with suturing. See **Table 9** for a composite of recommendations.[213]

Tongue Closure Technique

The first step with a tongue laceration is always anesthesia, which can be administered in a number of ways. For small lacerations, topical/local anesthesia can be achieved by placing gauze soaked in 4% lidocaine on the area for 5 minutes.[214] Local injection into the area of the laceration can be performed, though this tends to deform the tissues. Regional blocks may also be used and are highly effective. Either an inferior alveolar block or a lingual nerve block can be used. The lingual nerve block is performed by injecting local anesthetic into the base of the tongue posterior and medial to the most distal molar. A 25-gauge needle is inserted to 0.5 cm in children and 1 cm in adults. Inject 0.5-1.0 cc of local anesthetic, and use epinephrine if bleeding is an issue.[215]

Next, irrigate the tongue laceration. As the tongue often remains a moving target even after anesthesia, it can be grasped by placing gauze over the tip and holding it (or, if fully anesthetized, a towel clamp can be placed on the tip). The wound is then closed with an absorbable 4-0 to 5-0 suture. The sutures should pass through at least half the tongue's thickness, or the sutures can be placed through all 3 tongue layers in one pass (inferior mucosa, musculature, and superior mucosa). Tie the stitches loosely, because the tongue tends to swell to a significant extent; this can be facilitated by placing an instrument between the tongue and suture while tying the knot.[207] All sutures should have at least 4 tying throws, as the tongue's constant movement (more in some patients than in others) may untie knots.

Tongue Laceration Aftercare

Edema is common after tongue laceration closure. A single dose of dexamethasone (0.6 mg/kg) has been recommended by one source to help in significant cases of edema. There is no other literature available to support this approach to tongue edema.[213] Cold application (eg, ice, popsicles) can also reduce edema. A soft diet and mouth rinses are recommended for several days.[213]

Table 9. Tongue Laceration Closure Guidelines.

Consider Closing

- Large lacerations (> 1-2 cm)
- Large, gaping wounds, esp with the tongue at rest
- Wounds requiring suturing for hemostasis
- Anterior split tongue

Wounds Not Requiring Closure

- Small lacerations (< 1-2 cm)
- Non-gaping wounds

Lip Lacerations

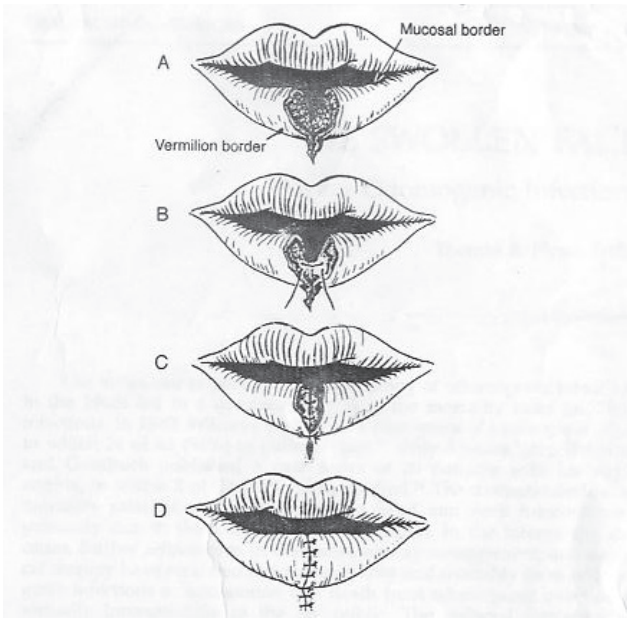
The lip is an area where one must be very meticulous in closure technique. Misalignment of as little as 1 mm in the lip's vermillion border is cosmetically obvious.[207] The preservation of the anatomic alignment of the vermillion border is thus what guides proper wound care and closure. (See **Figure 2**.)

Consider regional anesthesia for lacerations that involve the vermillion border; this prevents distortion of the anatomy and facilitates wound margin approximation. An infraorbital block can be used for the maxillary lip, and a mental nerve block can be used for the mandibular lip. Be aware that anesthesia provided by local injection may distort local anatomy. Consequently, local injection is best done with small injection volumes. If local injection is performed, consider first placing a stitch to approximate the vermillion border. It has also been suggested that an alignment mark can be made on the edges of the vermillion border with methylene blue or a marking pen. The available texts and review articles disagree on the use of this technique, some recommending it and some dismissing it. These recommendations are all based on anecdotal experience, and remain of indeterminate value.

After anesthesia the wound can be irrigated and un-

Figure 2. Technique For Closing A Lip Laceration.

A. Note the important anatomic line. B. The orbicularis oris muscle is closed first. C. Next, the vermillion border, or "white line," is carefully approximated. D. Finally, the remainder of the laceration is closed.



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dergo debridement. Debridement should be minimal, as the highly vascular lip can support relatively devascularized flaps. Closely examine the wound for foreign bodies (eg, teeth). If a tooth or part of one is missing, obtain an x-ray prior to closure. A missing piece of lip does not prevent primary closure, but if over 25% of the lip is missing, the recommendation is that the closure be performed by someone with significant expertise in cosmetic repairs.

Where appropriate, the first suture placed to close a lip laceration should meticulously approximate the vermillion border; then suture toward the wound's apex. Absorbable 4-0 to 5-0 suture is used for the mucosal surface and 5-0 to 6-0 nonabsorbable suture for the dermal surface. Through-and-through lacerations require that the lip's layers be closed individually: The muscular/fibrous layer is closed first, then the inner mucosa, followed finally by the outer mucosa. Quinn described the option of closing the muscular/fibrous layer and mucosa together as one unit, then closing the dermal surface.[216] Aftercare for lip lacerations is the same as for tongue lacerations.

Gingival Lacerations/Degloving

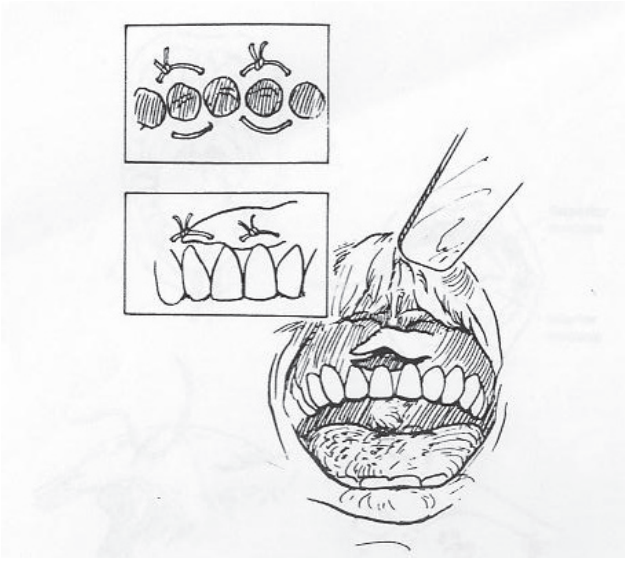
Gingival injuries can occur with mandibular or maxillary fractures. The gingiva can also deglove with local trauma. Typically, the gingiva can be stretched (with finger pressure) back to its pre-degloving size, even if it appears too small to do so. The tissue is then sutured in place with 4-0 or 5-0 absorbable (Vicryl™ or Maxon™) or silk sutures. The suture is anchored through the mucosa on the opposite side of the teeth. This is done by passing the suture between the teeth, then through the opposite mucosa, and back out between the teeth. (See **Figures 3 and 4**.) These sutures, even if absorbable, are typically taken out in a week, due to the location between the teeth.[207,215]

Antibiotics for Intraoral Lacerations

In a double-blind, placebo-controlled study, Steele et al showed that prescribing 5 days of penicillin VK significantly reduced the risk of infection in patients with intraoral lacerations. All wounds were full thickness or through-and-through. Penicillin reduced wound infections from 20% in the no prophylaxis group to 6.7% in the prophylaxis group ($p = 0.05$).[217] Penicillin should therefore be used for prophylaxis in intraoral wounds. Clindamycin may be substituted in patients allergic to penicillin, although no study has yet been done with clindamycin. The advantage of antibiotics for tongue lacerations is less clear. In the study by Lamell, none of the children were given antibiotics, and no infections occurred in 28 patients. This underpowered study suggests prophylactic antibiotics may not offer an advantage in lacerations of the tongue.[212]

Figure 3. Technique For Closing Avulsion Of Gingival Mucosal Tissue.

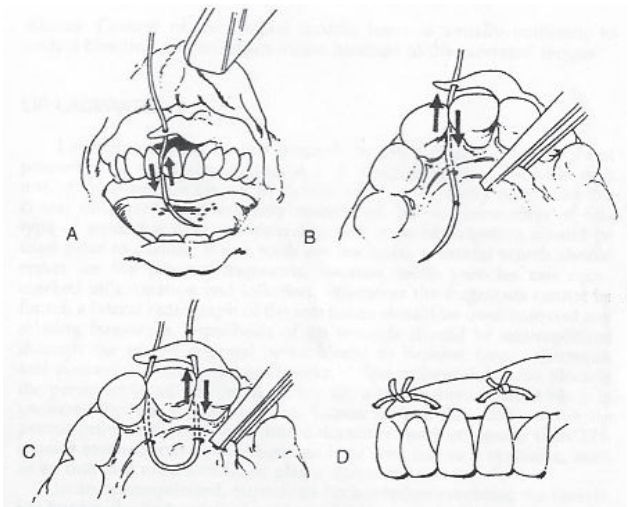
The technique to close this injury is shown. The sutures are brought around the teeth and through the avulsed tissue flap (insets).



Used with permission from: Trott A. Special Anatomic Sites. In: Weimer R, Cochran A, eds. *Wounds and Lacerations: Emergency Care and Closure*. St Louis, MO: Mosby-Year Book; 1991:172. Figure 1.

Figure 4. Technique For Closing Avulsion Of Gingival Mucosal Tissue When A Needle Cannot Be Passed Between The Teeth.

The technique of flossing the suture material through the teeth in cases in which the needle cannot be passed between the teeth because of tight interproximal contacts: A. Pass needle through facial tissue then floss through teeth. B. Pass needle through palatal tissue. C. Pass needle through palatal tissue again and floss through teeth. D. Tie suture on facial aspect.



Used with permission from: Trott A. Special Anatomic Sites. In: Weimer R, Cochran A, eds. *Wounds and Lacerations: Emergency Care and Closure*. St Louis, MO: Mosby-Year Book; 1991:172. Figure 2.

Controversies

No Irrigation

A study by Hollander found that the standard of care for wounds was often different for adults and children. Pediatric patients were less often irrigated than adults, yet despite this difference, children had a lower complication rate and better cosmetic outcome.[218] This raises a question of whether irrigation is required for wounds at low risk of infection. Another study by Hollander et al examined this question in low-risk wounds — defined as noncontaminated, nonbite face or scalp wounds that presented less than 6 hours after injury. Patients were excluded if they had high risk factors of renal disease, diabetes, or immune-compromised status. In this observational, cross-sectional study, 1090 wounds were treated with standard saline irrigation, and 833 wounds were treated with saline and gauze cleaning only. There was no significant difference in wound infection rate or cosmetic outcome between the groups.[219] This study was limited to low-risk facial and scalp wounds, was not randomized, and may have suffered from selection bias. Cleansing a wound without irrigation would likely only apply to very clean and low-risk areas, such as the face and scalp.

Cutting Edge

What does the future hold in wound care? The greatest advance will likely be in the use of growth factors to facilitate wound closure and healing, particularly in the wounds of difficult patients, such as elderly diabetics with peripheral vascular disease. There are numerous growth factors under evaluation. Significant products include epidermal growth factor (EGF), fibroblast growth factor (FGF), insulin-like growth factor (IGF), keratinocyte growth factor (KGF), and platelet-derived growth factor (PDGF).[220] All are being studied, and PDGF gel has been shown to speed healing of punch biopsy wounds. In the study by Cohen, PDGF healed punch biopsy wounds much quicker than controls — on day 22, 93% of PDGF wounds were healed compared to only 50% of controls ($p = 0.03$), and on day 24, it was 100% vs 57% ($p = 0.03$).[221] In a human study by Ehrlich, PDGF has also been shown to aide healing by promoting epithelialization, rather than by enhancing wound contraction.[222]

Another novel technique, right out of science fiction, involved the use of chambers filled with antibiotics and growth factors placed over a problem wound to facilitate its healing. Vranckx studied such a chamber filled with saline and antibiotics in 28 problem wounds in 20 patients. The wounds had failed to heal with standard conservative management, such as delayed primary closure and skin grafts. The patients for the most part had significant comorbidities of retained foreign body, diabetes, or steroid use for COPD, lupus, or rheumatoid arthritis. With the use of the chamber, 89% of wounds healed.[223] Expect to see more and more of these combinations of "enhanced" wound healing environments and the use of growth factors.

Table 10. Indications For Consultation.

Nerve injury
Vascular injury
Tendon or joint involvement (except possibly extensor tendon injury)
Difficult to remove foreign body
Complex laceration requiring extensive time commitment
High-pressure injection injury

Disposition

Almost all lacerations will be cared for in the ED then discharged. Follow-up can be with a primary care provider. ED follow-up is appropriate if the patient either has no primary care provider, or the primary care provider is uncomfortable handling wound care. Consultant referral has already been discussed for several specific types of lacerations, and is typically appropriate for any laceration involving deep structures, such as nerves, tendons, or joints. It is also appropriate for lacerations that will be very complex and time-consuming to close. (See **Table 10**.)

Summary

With proper knowledge of historical factors, one can determine if it is appropriate to close a wound primarily. The greatest concern is the prevention of a wound infection, for this leads to bad cosmetic outcomes as well as malpractice exposure. The risk of wound infections can be minimized by proper wound care and preparation techniques, such as high-pressure irrigation.

The emergency physician now has a multitude of wound closure methods to choose from, including the "needleless" method of tissue adhesives, and the standard

Key Points For Wound Care

- The standard for wound cleaning is high-pressure irrigation with normal saline or tap water.
- Clean wounds presenting within 8 hours of occurrence can typically be closed primarily. This does not apply to wounds on the face or scalp.
- Contaminated, infected, or high-risk wounds should be treated by delayed primary closure.
- Physical examination alone is inadequate for ruling out a foreign body in a wound.
- Small, intraoral lacerations do not require closure. ▲

techniques of stapling or suturing. These are all effective, and the well-versed emergency physician will be able to choose the best technique, providing the best outcome for patients.

Resolving the Introductory Examples

So what does the literature recommend for handling the 5 cases presented in the introduction?

- Case 1, the finger laceration, should be irrigated and, if small (< 2 cm), it can be left alone or closed primarily. If > 2 cm, it can be closed primarily, as it is a small, uncomplicated wound presenting early.
- Case 2, the leg laceration contaminated with fertilizer manure, should be irrigated and packed to allow for delayed primary closure. This is a high-risk wound, since it is highly contaminated with garden soil, and even though it occurred only 30 minutes before, it is at high risk of infection.
- Case 3, the child with a clean chin laceration, is likely one of the more common cases seen in the ED. This can easily be handled by applying LET, irrigating the wound, and using Dermabond® to close it.
- Case 4, the child with a tongue laceration from a fall — If the laceration is small (< 1-2 cm), does not bisect the tongue, and does not gape significantly at rest, it can be left alone. Otherwise, it should be closed with absorbable sutures (with sedation likely required).
- Case 5, the young man with a forehead laceration from a fight — If this is a simple laceration in a healthy young person, it could be irrigated and closed primarily, as it is 12 hours or less old (the same is likely true up to 24 hours). ▲

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Evidence-based medicine requires a critical appraisal of the literature based upon study methodology and number of subjects. 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, such as the type of study and the number of patients in the study, will be included in bold type following the reference, where available. In addition, the most informative references cited in the paper, as determined by the authors, will be noted by an asterisk (*) next to the reference number.

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Physician CME Questions

33. A diabetic presents 24 hours after cutting his arm with a dirty knife. How do you treat the wound?
a. It should be cleaned with saline and gauze and closed primarily.
b. It should be irrigated with saline using a high-pressure technique and closed primarily.
c. It should be left open to heal by secondary intention.
d. It should be irrigated with saline using a high-pressure technique and closed in 3-4 days with DPC.

34. A 4-year old presents 5 hours after cutting his forehead on a coffee table. How do you treat the wound?
a. It should be irrigated and closed primarily.
b. It should be irrigated and closed by DPC, as the normal cutoff for closing clean facial wounds is 4 hours.
c. It may do well with gauze and saline cleaning (without high pressure) and primary closure.
d. A and C are possible.

35. In a wound with a possible foreign body in it:
a. a good physical exam rules out a retained foreign body.
b. glass over 2 mm in size shows up on most x-rays.
c. wood is best found by CT or MRI; US can also be considered.
d. B and C

36. A 20-year old presents with a stellate laceration heavily contaminated with soil 2 hours after it occurred:
a. He is a good candidate for primary closure, as he is under 6-10 hours, which is the range accepted as a "golden period" for extremities.
b. He is a candidate for primary closure after copious irrigation with a bulb syringe.
c. The wound should be irrigated with a high-pressure technique and closed in 3-4 days by DPC.
d. The wound can be closed primarily without increased risk, if he is copiously irrigated by a high-pressure technique.

37. Tongue lacerations that should be considered for closure are those:
a. less than 1 cm in size
b. those with no bleeding
c. those that do not gape
d. a large anterior bisecting laceration

38. If povidone-iodine solution is to be used for irrigation, it should be at what strength?
a. 0.1%
b. 1.0%
c. 10%
d. 100%

39. The proper technique for wound irrigation is:
a. using a 35-cc syringe and 19-gauge catheter
b. using a bulb syringe with large volumes
c. poking a needle hole in an IV bag and squeezing it
d. none of the above

40. A fluid that has recently proven as effective as saline is:
a. 10% povidone iodine
b. benzalkonium chloride
c. dilute hydrogen peroxide
d. potable tap water

41. A 4-year old with a scalp laceration is best closed with:
a. staples
b. sutures
c. hair apposition technique
d. all of the above

42. Topical LET anesthesia is:
a. best used in a pediatric patient with a facial laceration.
b. best used in an adult with a thigh laceration.
c. superior to EMLA cream for extremity anesthesia.
d. none of the above

43. A laceration over a knee can be closed with:
a. cyanoacrylate
b. staples
c. Steri-Strips™
d. none of the above

44. Cyanoacrylates:
a. can be used in low-tension areas where one would normally use a 5-0 suture.
b. should have bacitracin applied as a dressing for aftercare.
c. have a similar cosmetic outcome to sutures in the proper setting.
d. both a and c

45. Delayed primary closure:
a. is an underused technique.
b. is the recommended technique for contaminated wounds.
c. should be considered for wounds that are delayed in presentation to the ED.
d. all of the above

46. **Delayed primary closure:**
    a. does not require wound cleansing on presentation.
    b. involves the wound being seen within 24 hours and closed at that time.
    c. is the procedure of choice for early presenting, clean wounds.
    d. none of the above

47. **Wound preparations may include:**
    a. shaving of the wound, as this reduces infection rate.
    b. povidone iodine on the intact skin around the wound, as well as in the wound itself.
    c. removal of hair via an atraumatic surgical clipper.
    d. soaking of the wound in iodine, then shaving to maximize sterilization.

48. **Lip lacerations:**
    a. usually heal without suturing.
    b. require meticulous approximation of the vermillion border.
    c. are best anesthetized with a lot of local injection.
    d. never contain retained teeth as foreign bodies.

Class Of Evidence Definitions

Each action in the clinical pathways section of *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
- Non-randomized or retrospective studies: historic, cohort, or case-
- control studies
- Less robust RCTs
- 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

Significantly modified from: The Emergency Cardiovascular Care Committees of the American Heart Association and representatives from the resuscitation councils of ILCOR: How to Develop Evidence-Based Guidelines for Emergency Cardiac Care: Quality of Evidence and Classes of Recommendations; also: Anonymous. Guidelines for cardiopulmonary resuscitation and emergency cardiac care. Emergency Cardiac Care Committee and Subcommittees, American Heart Association. Part IX. Ensuring effectiveness of community-wide emergency cardiac care. *JAMA* 1992;268(16):2289-2295.

Physician CME Information

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Target Audience: This enduring material is designed for emergency medicine physicians.

Needs Assessment: The need for this educational activity was determined by a survey of medical staff, including the editorial board of this publication; review of morbidity and mortality data from the CDC, AHA, NCHS, and ACEP; and evaluation of prior activities for emergency physicians.

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