A RATIONAL APPROACH TO THE OUTPATIENT MANAGEMENT OF LACERATIONS IN THE PEDIATRIC PATIENT

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Summary

The repair of skin lacerations is a significant part of pediatric care. Minor trauma is the leading diagnostic category for pediatric acute care, constituting 22 % of visits to pediatric emergency departments (EDs)[1] and 42 % of visits to general community EDs.[2] Lacerations account for over a quarter of minor injury visits and comprise between 4.4 and 11 % of all visits.[2,3] Many are within the scope of practice of the non-surgeon, and the majority are 2 cm in length or less.[4]

Unfortunately, many common precepts surrounding wound care are controversial and lack scientific foundation.[5] A widely accepted standard of care does not exist, and, even when sound evidence favors specific practices, contradictory or even harmful practices remain common.[6] The wound care education of clinicians who treat children appears to be highly variable. Many clinicians develop their wound repair practices by word-of-mouth and by other forms of informal training. Pediatric training may involve between zero and 6 months per year in emergency rotations.[7] One cohort of pediatric residents spent 5-6 months of ED rotations through 3 years of training and performed a median of 14 laceration repairs, ranging from as few as 1 to as many as 24 in any year.[8]

The wound care literature contains an overwhelming number of articles whose conclusions are often contradictory. Further, much of the work on important aspects of care was published without careful attention to sample size, study design, and statistical analysis. The generally good outcomes of simple lacerations are probably due more to the patient's innate healing capacity than to medical intervention. Nonetheless, it is prudent to identify and adhere to principles of wound care which are proven to contribute to optimal results. This article reviews the major aspects of wound care and attempts to distinguish scientifically valid concepts from unfounded oral tradition in order to identify the most sound clinical practices. After a review of wound healing, the sections follow a sequence similar to the typical wound care encounter: evaluation; local anesthesia, wound preparation; general closure techniques; specific wound types; and aftercare. Finally, the article concludes with sections on problems commonly associated with pediatric care, namely, the parental request for a surgical specialist, and the anxious or uncooperative child.

Wound Physiology

The tissue layers relevant to lacerations are the epidermis, dermis, subcutaneous tissue, and deep fascia (Figure 1). The epidermis is the keratinized epithelium which rests on the thicker dermis. These layers, which together constitute the skin, are tightly adherent and clinically indistinguishable. Approximation of the dermis provides the strength and alignment of skin closure. The subcutaneous layer is a fascial plane seen clinically as fat within the wound, and contributes little to the strength of a repair. Investing the underlying muscle and occasionally requiring repair is the deep fascial layer.

The mechanism of wounding predicts wound outcomes. Shear forces resulting from sharp objects have better cosmetic outcomes and fewer complications than those produced by impact mechanisms. Tension forces from blunt injuries and compressive forces from crush injuries deliver more energy to a larger amount of tissue and cause greater disruption and higher infection rates.[9] Host factors affecting wound healing include renal function, diabetes, nutritional status, obesity, and corticosteroid or other immunosuppressive therapy.[5,10] Young age appears to be an advantage, with patients < 15 years of age experiencing infection rates < 1 % for clean surgical wounds.[10] Children also experience lower infection rates and better cosmetic outcomes following wound repair than adults, although this may be a function of more favorable wound types and locations.[11]

The healing of a wound is a complex interaction of physiologic processes.[12] Inflammation brings phagocytes to consume bacteria, debris and non-viable tissue. New blood vessels appear and contribute to the early erythematous appearance of uninfected healing wounds. Fibroblasts proliferate and synthesize new collagen. Remodeling involves a balance of collagen synthesis, lysis and cross-linking with a nadir in tensile strength approximately one week after wounding. The wound matures and develops its ultimate strength and appearance over 6 to 12 months.

Evaluation

Attention to the wound and its repair should await a rapid trauma evaluation. The primary survey focuses on airway patency, ventilation, cervical spinal stability, hemodynamic stability, and CNS function. In most cases, the patient's vital functions will be completely intact, and a more leisurely general examination and directed wound evaluation may proceed. Specific historical factors related to the injury include time elapsed since wounding, wound mechanism, care rendered prior to evaluation, associated injuries, and a consideration of the possibility of inflicted trauma. A history which is inconsistent with the severity of the injury or the child's developmental stage, or which changes over time, should arouse suspicion.

Assessment of the wound includes a general description of location, size, and shape. Documentation of distal perfusion and sensorimotor function is important with extremity injuries and should be assessed before administration of anesthetics. Nerve and tendon functions are often difficult to elicit in the pre-verbal child. Observation of spontaneous activity provides an indirect measure of function. Abnormal position or unopposed flexion or extension may suggest a tendon injury. Compression over the volar forearm will elicit finger movement if flexor tendons are intact. Loss of innervation results in anhydrosis and lack of wrinkling after immersion in water. Palpation and exploration help to exclude the possibility of a retained foreign body or injury to deep structures, but are best conducted after the onset of local anesthesia.

Radiographs rarely alter management except in the case of suspected foreign body or underlying long bone fracture. Glass objects are nearly uniformly radio-opaque[13] and reliably detected in the 1-2 mm range.[14] Plain films serve to document their presence, absence, or successful removal. Although the presence of an underlying long bone fracture dramatically alters management, routine skull radiography in scalp lacerations is unnecessary if aggressive exploration and palpation can be conducted under local anesthesia.

Wound Anesthesia

Effective local anesthesia is crucial to wound care, and the variety of injected and topical agents permits considerable versatility in providing pain relief. Numerous methods for reducing the pain of anesthesia have been described, and expertise in delivery produces surprisingly calm patients, grateful parents and optimal procedure conditions. Although surgical traditional dictates the creation of a sterile field before administration of local anesthesia, few patients will tolerate an adequate cleansing or wound exploration without pain relief. Therefore, with the possible exception of a gentle initial cleansing, all wound care procedures should begin with attention to effective local anesthesia.

Infiltration Anesthesia

Lidocaine is a widely available anesthetic with proven safety and efficacy, rapid onset and a duration of action well suited for laceration repair. True allergies are extremely uncommon,[5] and toxicity, primarily manifested as seizures[15,16] and rarely death,[17] occurs only with extremes of dosing. Recommended maximum doses for infiltration are 5 mg/kg of plain lidocaine and 7 mg/kg of lidocaine with epinephrine (0.5 and 0.7 ml/kg of 1 % solution, respectively). Discomfort may recur after lidocaine effect has ended, and bupivacaine is useful when prolonged anesthesia is desired (4-6 hours).[18,19] Life-threatening cardiotoxicity occurs more readily with bupivacaine than with lidocaine,[20] and doses should not exceed 2-3 mg/kg.

Mixtures of the 2 anesthetics are often used with the intention of combining the rapid onset of lidocaine and the prolonged duration of bupivacaine. Such combinations do not appear to cause synergistic neurologic or cardiovascular toxicity.[20] Unfortunately, no improvement in rapidity of onset occurred in studies of intradermal,[21] subcutaneous,[22] and peripheral nerve[23] anesthesia. A small volunteer study found that onset occurs within 2 minutes for the majority of "subdermal" injections of either drug and within 5 minutes for the remainder.[18] A larger clinical study found no significant difference with mean onset times of 3.0 minutes for lidocaine and 3.5 minutes for bupivacaine.[19] Other studies, involving deep nerves of long anesthetic latency,[24,25] have found improved onset with mixtures of rapid acting and long acting agents. Taken together, the studies suggest that onset is hastened by the addition of lidocaine to bupivacaine but that clinically important advantages disappear in the more superficial locations encountered in wound repair. In most circumstances, use of bupivacaine as a single agent is satisfactory, although some patients may find prolonged anesthesia disagreeable and may incur inadvertent trauma, particularly around the mouth.

For the rare patient with a plausible history of allergic reaction to amide anesthetics (lidocaine, bupivacaine), an ester type anesthetic (procaine, tetracaine) may be used.[5] More commonly, patients develop allergies to the ester group and require preservative-free (cardiac) lidocaine, to avoid cross-reaction with the methylparaben preservative.[26] Recently, injectable diphenhydramine diluted in saline to 0.5 to 1 % (5 to 10 mg/ml) has been shown to be an effective alternative to standard amide and ester anesthetics.[27]

The addition of epinephrine in low concentrations (1:200 000 to 1:100 000) facilitates hemostasis and, by limiting uptake from injection sites, extends the duration of anesthesia and permits larger doses to be given safely. In unwounded volunteers, 1:100 000 epinephrine extended the effect of lidocaine to 3 hours on the face and nearly 10 hours on the lower extremity.[28] A reasonable practice is to use epinephrine-containing anesthetics in all wounds except those near end-arterial distributions (digits, penis, tip of ears and nose) and other regions where decreased perfusion is poorly tolerated (narrow flaps or infected wounds). Although most conveniently purchased as stock solutions, the combination of 0.05 to 0.1 ml of epinephrine (1:1000) with 10 ml of anesthetic provides 1:200 000 to 1:100 000 concentrations.

Strategies for Less Painful Injection

Patient satisfaction depends heavily on the non-anesthetic aspects of injection. Buffering with sodium bicarbonate (8.4 %) in 1:9 or 1:10 ratios[29-31] reduces the pain of anesthetic preparations with and without epinephrine[29,32] with no increased risk of infection.[33] Smaller needle sizes may interact additively with buffered anesthetics to reduce pain of infiltration.[34] Anesthetics buffered in advance may retain comparable efficacy after 1 week at room temperature.[35,36] Epinephrine in buffered mixtures undergoes degradation by approximately 25 % per week,[37] although no loss of clinical efficacy is apparent.[36] Solutions warmed to 40-42^{o} C[38,39] also decrease the pain of injection but are less practical, especially as the effect disappears at 37^{o} C.[40]

More of the pain of injection comes from tissue distention and burning caused by the drug than the needle puncture. Longer, narrower needles (typically 27-30 gauge, up to 1.5 in) help to control the rate and volume of injection. Studies on injection speed are conflicting, with volunteers reporting either no improvement[41] or significant reductions in pain[42] during slow injections given at one location. Significant pain relief does occur when anesthetic is injected slowly along the entire needle track,[40] a technique which more closely approximates clinical practice. Regardless of its direct effect on nociception, a slow injection allows the clinician to engage in distraction or other behavioral strategies. Agitation of skin over the injection site may interfere with pain transmission, although objective clinical data are lacking.[43] The finger which agitates the skin also provides tactile information concerning the distribution of drug and degree of tissue distention. Infiltrating as the needle is being withdrawn is a pragmatic measure, as an adequate trail of anesthetic may be deposited even in the event of sudden patient movement.

Placement of the injected solution is equally important. Puncture through wound edges is less painful than through intact skin for subcutaneous[44] and intradermal injections.[45] Infiltration below the dermis is much less painful than within the dermis,[40] although the onset of anesthesia may be delayed slightly. Where practical, initiating the infiltration of the wound at a location closest to its nerve supply may provide partial anesthesia during the completion of infiltration. Initiating the puncture at the apices of the wound allows the needle to travel the length of the wound edge. A field block created by directing the needle outward at an angle from the apices provides a wide rectangular zone of anesthesia with a minimal number of punctures.

Nerve blocks are useful when the region is particularly painful to infiltrate, when the wound is extensive, or when direct infiltration will distort the local anatomy. The techniques most useful in pediatric patients are digital and facial nerve blocks. These are described in detail elsewhere; however, I find certain variations more practical. Digital blocks performed at the level of the metacarpal head[46] appear less painful and need less supplementation because larger volumes may be injected than over the proximal phalanx. The intraoral blockade of infraorbital[47] and mental[48] nerves may be less painful than the traditional percutaneous approach and may be preceded by an application of viscous lidocaine.

School age and older children may benefit from techniques of imagery. A distracting conversation appears to decrease the perceived pain of anesthetic injection and should begin well before the patient is aware of the syringe and needle. A useful conversional gambit is to begin by asking the patient to name a favorite activity and then to guide the patient through a open-ended conversation:

> "What kinds of things do you like to do/wish you could be doing now?"
>
> "Go to the zoo? Let's imagine you're there now. Who's there with you?"
>
> "Tell me what you're doing."

With older children, it is useful to forewarn of possible pain and to empower the child to tell the clinician any time pain is felt. With distraction and a promise that infiltration will be slowed or temporarily suspended when there is pain, many patients readily tolerate large volumes of anesthetic injection.

Topical Anesthesia

Topical anesthetics are particularly valuable in pediatrics. Although not effective on lacerations,[49] topical lidocaine is useful on abrasions, prior to cleansing, and on mucosal surfaces, in preparation for anesthetic injection. A 10 minute application of 1 % tetracaine may reduce the pain of subsequent lidocaine infiltration, but the degree of pain relief is of uncertain clinical significance.[50]

Various formulations of tetracaine-adrenaline-cocaine solution (TAC) have gained popularity for topical anesthesia. Their main use is in pediatric patients old enough to understand and appreciate the elimination of injection pain. TAC is most effective on superficial lacerations of the face, head and neck, avoids tissue distention, and may provide hemostasis due to its vasoconstrictive properties. Because of this property, TAC should not be used in regions with end-arterial circulation, compromised vascular supply, established infection, or gross contamination.

Dosage has not been studied, but extrapolation from adult mucosal application suggests 0.9 ml/kg of full strength (11.8 % cocaine) TAC,[51] while others recommend a fixed dose for all patients. Low concentrations of cocaine are detectable in asymptomatic children,[52] but TAC is said to be free of toxicity when used correctly.[53] Reported local and systemic toxicity includes: corneal abrasions and mydriasis following ocular application;[54] mental status changes following mucous membrane contact[54] or oral ingestion;[55] seizures after application to scald burns[56] and to mucous membranes;[57] and death following mucosal contact.[58] A recent report suggesting that shallow mucosal lacerations < 2 cm can be safely anesthetized with 2 drops of TAC on an applicator[59] is best considered with caution as the small sample included wounds which may not require sutures.

Removal of debris and clotted blood may enhance local absorption.[53] TAC is applied to the wound for 20-30 minute, after which blanching serves as an indirect marker of anesthetic effectiveness. Incomplete anesthesia occurs in 20 % of all cases and in half of trunk and extremity lacerations.[51] Second applications of TAC are not recommended,[52,53] as supplemental lidocaine injection through partially anesthetized surfaces is preferred.

Alternatives to TAC have been sought, the best studied of which is lidocaine-epinephrine-tetracaine (LET).[60-62] This combination provides the advantages of TAC without the expense, toxicity and substance control issues of cocaine. Other anesthetic-vasoconstrictor combinations have been tested,[4,63] but, their advantages over LET are unknown.

The eutectic mixture of local anesthetics (EMLA) is a cream containing lidocaine (2.5 %) and prilocaine (2.5 %). A 60 minute application provides effective dermal anesthesia for minor procedures such as vascular access, lumbar puncture[64] and circumcision.[65] Early work demonstrates its superiority over TAC for extremity lacerations.[66] However, more experience with potential adverse effects, including local tissue toxicity[67] and methemoglobinemia,[68] is warranted before this agent can be recommended for wound anesthesia.

Recommendations for Optimal Local Anesthesia

The optimal wound anesthetic is convenient and painless. Unfortunately, neither TAC nor LET is available as a stock solution, and on-site compounding is impractical unless a facility treats a high volume of patients with lacerations. Even when topical anesthetic is available, some patients and their wounds are not suitable candidates. Therefore, skill with infiltration anesthesia is indispensable. Except with nerve blocks, needles larger than 27 or 30 gauge are unnecessary. Slow injection of a minimal quantity of buffered anesthetic through the laceration into a plane immediately beneath the dermis decreases pain. Time invested in distraction and delivery technique early in the procedure will be repaid manifold with cooperation during the repair.

Wound Preparation

Antisepsis

Sterility in wound care. Although sterile technique is commonly exercised in wound repair, even the cleanest wounds contain bacteria and other particulate matter. Although prudent to minimize this load, excessive efforts to sterilize the wound are both futile and unnecessary. Normal hosts resist infection quite well, and intradermal injection of 10^6 organisms[69] or wound colonization on the order of 10^5/gm[70] are required to establish infection. The data on sterile gloves are scant and conflicting and demonstrate no significant benefit[71] or only minor reductions in late infections.[72] The practice, in developing countries, of using gloves and suture kits for multiple patients is associated with infection in only 2.5 %.[73] The use of masks is less well studied.[74] While these data point out the illogic of obsessive attempts to achieve sterility, it is prudent to use sterile supplies, primarily to avoid the introduction of extraneous foreign material or pathogens.

Antiseptic toxicity. Although detergent-containing antiseptics decrease the infection rates of elective procedures,[10] the same is not true for injured skin. The common practice of soaking wounds in saline or povidone-iodine solutions does not reduce bacterial concentrations or subsequent infection rates.[75] Time-honored topical treatments pose a risk of significant tissue toxicity.[76,77] Alcohol containing disinfectants act as tissue fixatives, resulting in irreversible damage.[78] Irrigation with hydrogen peroxide has been implicated in the development of large regions of subcutaneous emphysema,[79,80] and mere application to wounded tissue results in local microvascular blockage.[78] Surgical scrub solutions (hexachlorophene *scrub* [pHisoHex], povidone-iodine *scrub*) cause significant tissue irritation and promote infection in contaminated wounds,[77,81] because of their anionic detergent components.[82] Chlorhexidine (Hibiclens) has comparable tissue toxicity despite the absence of potent detergents.[81]

Povidone-iodine. Some authors object to the use of povidone-iodine of any kind in open wounds[83] and cite data showing cytotoxicity to fibroblast suspensions and impaired healing of open wounds subject to repeated irrigation.[84] However, such studies do not approach clinical reality, and animal studies have shown a single irrigation with povidone-iodine solution to reduce infection rates.[85] Other studies attest to the benign nature of povidone-iodine solution. Among common disinfectants tested, 1 % povidone-iodine and 3 % hexachlorophene solutions produced no injury after direct application to wounds, providing no other excipients were added.[78] Intra-articular injection of 5 % povidone-iodine solution causes minimal histologic change.[76] Preoperative soaking with 1 % povidone-iodine solution does not affect the tensile strength of sutured wounds[86] or damage local tissue defenses.[77] Even the direct application of a dry powder of povidone-iodine to experimental, non-contaminated wounds had no adverse effect on rates of infection, histologic appearance and wound strength.[87]

Clinical studies on wound disinfection are limited. Traumatic wounds scrubbed for 60 seconds with 1 % povidone-iodine solution experienced a threefold decrease in infection rates.[88] Unfortunately, the contribution of povidone-iodine is unclear, because control wounds did not undergo a scrub with any agent. In pediatric appendectomies, 1 % povidone-iodine sprayed during wound closure reduced rates of infection with no adverse effect on leukocyte migration or cellular architecture.[89]

Surfactant cleansers. The non-ionic surfactant poloxamer 188 (ShurClens, ConvaTec) is also safe and useful for wound decontamination. Although possessing no anti-bacterial activity, it decreases the mechanical trauma of scrubbing, with no evidence of cytotoxicity or interference with wound healing, while reducing bacterial load and incidence of infection.[81,90,91] A high porosity sponge (Optipore, ConvaTec) is typically used with the surfactant to decrease local trauma[90] and creates a convenient system for removal of "road rash" to prevent a long lasting traumatic "tattoo."

The true benefit of povidone-iodine is difficult to quantify; however, it is reasonable to apply 1 % povidone-iodine, a 1:9 dilution of the stock 10% solution, to the open wound and surrounding skin both for initial cleansing prior to anesthetic injection and during more aggressive wound toilet after anesthesia. Some recommend wound closure leaving povidone-iodine in the wound cavity.[12] However, its use on intact skin is associated with subclinical alteration of thyroid function,[92,93] and I prefer to remove any residue before closure. Most wounds do not require the additional time and expense of a surfactant cleanser. However, selected wounds with significant contamination or wounds to be cleansed without anesthesia may benefit.

Shaving

A traditional practice for wounds in hair bearing areas is the pre-operative shave. Although hair removal may improve the ease of closure, the benefit to the patient is questionable. Razor shaving before elective operations increases wound infection rates compared with depilatory preparation,[94] clipping,[95] and preparation without hair removal.[10] Closure without hair removal is preferable in all cases and especially around the eyebrow, which serves as a landmark and grows back unpredictably if shaven. For simple scalp lacerations requiring only percutaneous sutures, hair may be kept from the wound by application of antibiotic ointment, lubricating gel, or even the prep solution. For wounds requiring deep sutures or surrounded by extremely untidy hair, conservative scissor clipping at each wound edge is recommended. The resulting stubble will neither interfere with wound repair nor be associated with minor trauma which promotes infection.

Irrigation

Far more crucial than antisepsis to the outcome of skin lacerations is aggressive decontamination with high pressure irrigation. The combination of a 35 ml syringe and 19 gauge needle generates peak pressures within the syringe of 35 psi.[96] During *in vitro* and animal experiments, this system produces a calculated wound surface pressure of 7 psi, with reduction in bacterial load and incidence of infection.[97] The syringe-needle method is superior to the low pressure irrigation (0.05 psi) of a bulb syringe.[98] Other systems, such as saline bottles or bags with perforations or nozzles generate only intermediate pressures when compressed by hand or pressure cuff.[96,99] Their clinical performance has not been directly compared with the syringe-needle technique and, if proven equivalent, may be less tiring and time-consuming.

The optimal irrigant is unknown; however, povidone-iodine solutions and surfactants do not appear to be superior to normal saline in preventing infection.[100] Other widely available, but less physiologic, solutions such as sterile water may result in tissue injury.[78] In the absence of data to the contrary, normal saline appears to be the most practical solution based on cost, availability, and lack of local or systemic toxicity.

The appropriate volume of irrigation is little studied. As 150 ml saline irrigations proved beneficial in contaminated 3 cm animal lacerations,[97] 50 ml/cm may be appropriate for human wounds, and larger volumes are unlikely to be harmful. In reality, the average pediatric laceration is at low risk of infection, and studies of impractically large size would be needed to demonstrate the advantages of different wound care practices. For example, one study, limited by poor followup and lack of randomization and uniformity of technique, could find no difference in infection rates of irrigated (0.9 %) and unirrigated (1.4 %) face and scalp wounds.[101]

My practice is to irrigate the average wound with at least 150-250 ml of normal saline (50-100 ml/cm of laceration, modified by depth and degree of contamination). The irrigation system is a 30 ml syringe fitted with a commercially available nozzle molded into a clear plastic cup (Zerowet Splashshield) to prevent splash and infectious exposure. When this device is unavailable, 18 or 20 gauge IV catheters are used. Despite potential dissipation of pressure in plastic IV catheters, they are preferable in the pediatric setting because of the risk of needle puncture injury during unexpected movements. Ballooning of tissues is said to be a risk of placing catheters into the wound. However, this occurs even when the syringe is held outside of the wound, and it is unreasonable to compromise pressure or volume simply to avoid retention of fluid. Wound irrigant spreads into adjacent tissues for short distances but does not appear to cause dissemination of bacteria.[102] Tissue damage and susceptibility to infection resulting from irrigation are theoretical concerns, but has only been demonstrated experimentally when wounds were contaminated *after* irrigation.[102] For large or contaminated wounds, a liter bag of saline connected by IV tubing and stopcock to the syringe and catheter creates an efficient high volume irrigation system. The irrigation session is also well spent exploring for foreign bodies and deep structure injuries.

Body fluid precautions must be exercised during wound irrigation. Without barriers, potentially infectious fluid may be sprayed about. Commercial devices, the clinician's gloved hand, or strategically placed gauze sponges will channel the high pressure irrigant. Gowns and eye protection are always a prudent consideration. Planning ahead for fluid runoff will save time cleaning up later. Devices designed to collect fluid are convenient but raise the question of disease transmission. Although less elegant, several layers of towels over an absorbent-waterproof pad are simpler and more practical to use.

Wound Revision and Debridement

The indications for excision of tissue include extremely irregular or oblique wound edges, or obviously non-viable tissue remnants. However, most simple pediatric lacerations do not require excision or revision of injured tissue. The dermis should be debrided sparingly, if at all, as excessive skin tension makes approximation difficult and excessive scarring more likely. Although it is tempting to excise complex wound edges in order to simplify a closure, meticulous repair of irregular wound edges results in superior cosmetic results. The subcutaneous layer, in distinction, may be more generously debrided, if there is contamination or non-viable tissue, which may interfere with leukocyte function and promote bacterial proliferation.[103] On occasion, wounds may require extension in order to achieve adequate exposure. However, because a longer scar results, this should be performed only with the intention of primary repair of an underlying structure.

Hemostasis

Most wounds no longer bleed by the time they present to medical attention. Direct pressure and elevation achieve hemostasis in the majority of those which do bleed. Properly applied, this technique will stabilize hemorrhage in all except the most severe vascular injuries. If no contraindication exists, an epinephrine containing anesthetic provides a theoretical advantage. In many cases of mild, non-pulsatile bleeding, suture closure will correct the situation. The distal phalanx and nail bed are very vascular. Tourniquet control may be achieved with a Penrose drain at the base of the digit, after exsanguination from distal to proximal with a gauze wrap. Bleeding will persist in a very small minority. Vessels may be clamped and ligated under direct visualization, but extreme caution is necessary, particularly in the extremities, to avoid damage to adjacent structures or to a salvageable vascular injury. Injuries with bleeding beyond the capacity of the clinician are best covered with a pressure dressing and referred for immediate consultation.

Wound Closure

The goal of wound closure is approximation of skin under minimal tension while achieving wound edge eversion. Although closure of dead space is frequently advised, its value is controversial. Sutures placed in fat contribute no strength to the repair and fail to prevent hematoma and infection.[104] Although large soft tissue defects promote infection in contaminated experimental wounds, the addition of suture material to muscle or fat, even without tension, further increases the rate of infection.[105] Similarly, the presence of drains increases the risk of wound infection.[10,106] The clinician should, therefore, place only enough subcutaneous sutures to restore anatomic and functional integrity.

Instruments

A wide variety of instruments is used in wound repair, and most disposable trays include at least 4 or 5 instruments. However, 3 instruments suffice for most outpatient wound repairs: a needle holder, toothed forceps, and suture scissors. An acceptable needleholder, regardless of style, must have at minimum: jaws which close completely without engaging the locking mechanism and do not permit the passage of light when viewed in profile; jaws which grasp securely the finest suture anywhere along their surfaces without engaging the locking mechanism; and a locking mechanism which closes and opens easily, securely, and smoothly. Toothed forceps require less force to grasp tissues and are less damaging than those without teeth. Forceps without teeth are best reserved for the removal of small foreign bodies and for dissection of the nail plate from the nail bed. Unfortunately, many non-surgeons are at the mercy of purchasing decisions based entirely on cost savings. The result is a low cost tray with disposable instruments of inconsistent quality. Unless he or she is willing to endure a suboptimal repair experience with frequent false starts, the clinician should be prepared to open a new kit if even one of the instruments is slightly below par.

Occasionally, retraction of skin edges is required for adequate exposure of deeper tissues. Self-retaining retractors and skin hooks are useful but often too costly for the clinician who sutures complex wounds infrequently. A simple substitute may be created by bending a tight curve in the tip of a 25 gauge needle mounted on an empty syringe.

A final adjunct often underutilized in outpatient wound care is adequate lighting. Although permanently mounted overhead lights are not practical for most pediatric settings, any portable lamp whose beam can be fixed on the wound is invaluable, particularly for exploration or deep suture placement.

Suture Materials

A complete description of suture materials entails numerous characteristics, including physical composition, handling characteristics and interaction with tissue (Table 1).[107,108] While most of these characteristics result in only subtle differences, a useful generalization is that synthetic materials resist infection better than natural materials and monofilamant possibly better than braided materials.[109,110] For most clinicians performing outpatient wound care the most practical classification is by division into absorbable and nonabsorbable types, whose uses are outlined below.

Absorbable materials. "Catgut," or surgical gut, is a natural absorbable material composed of collagen from bovine or sheep intestine. Plain and fast-absorbing gut sutures lose tensile strength rapidly (4-5 days) and are useful when prompt removal is desirable but impractical, such as on the face of the fearful young child. Nontheless, many clinicians comply with an unsupported dogma prohibiting the use of percutaneous gut sutures because of fear of tissue "reactivity." Although inflammation is required for the phagocytosis of gut suture, its relation to long-term scarring is not proven. Facial closure with plain gut, during aesthetic[111,112] and wound repair[113] procedures, produces long term cosmetic results comparable to those obtained with nonabsorbable suture. Chromic gut provides somewhat longer wound security (approximately 14 days) and is useful for intraoral lacerations, fingertip avulsions and scalp lacerations under minimal tension.[114]

Synthetic absorbable sutures have many features distinguishing them, but have the common characteristic of retaining tensile strength long enough to ensure the security of subcutaneous layers after the removal of percutaneous sutures. Polyglycolic acid (Dexon, Davis & Geck) and polyglactin 910 (Vicryl, Ethicon) are braided synthetic materials which retain 50 % of initial strength at 4 weeks. Polyglyconate (Maxon, Davis & Geck) and polydiaxanone (PDS, Ethicon) are monofilament synthetic materials with prolonged duration of tensile strength. A new rapidly absorbing, lower molecular weight polymer of polyglactin 910 (Vicryl Rapide, Ethicon) has been marketed for percutaneous wound closure, but its superiority over gut suture remains unproven.

Non-absorbable materials. Monofilament synthetic materials such as nylon and polypropylene are the most commonly used non-absorbable sutures for traumatic wounds. Natural materials such as silk possess optimal handling characteristics but are more likely to produce tissue reactivity and infection. Nylon and polypropylene possess excellent tensile strength with negligible tissue reactivity, but are somewhat stiff and require more "throws" to create a secure knot. Polybutester is a similar monfilament synthetic material which possesses the additional characteristics of pliability and early elasticity.[108] Although potentially useful in the presence of wound edema, experience with polybutester in wound care is limited. With the exception of tendon repair, non-absorbable materials require removal within a time frame appropriate to the anatomic region (Table 2).

Needle types. Of the many available needle styles, the most appropriate for skin repair is a 3/8 circle, cutting needle. The point of this needle has a triangular cross section which facilitates passage through dermis. The terms "conventional" and "reverse" designate whether the sharp edge of the point is on the inner or the outer curvature of the cutting needle. The theoretical tendency of conventional cutting needles to cause sutures to cut into tissues is unlikely to affect the average wound closure. Standard cutaneous and precision (plastic) grades of cutting needles are distinguished by their sharpness.

Standard skin needles (FS series, Ethicon; CE series, Davis & Geck) are suitable for the scalp, trunk and extremities. Finer sutures on the face require a smaller and more sharply honed needle (P, PS, and PC series, Ethicon; PRE series, Davis & Geck). Specific needles are identified by letters corresponding to needle style and a number corresponding to size. The numbering systems are confusingly specific to each manufacturer and needle style, but, in most cases, the needle silhouette is diagrammed on the package.

Alternatives to Standard Suture Material

In a busy clinical setting, rapid, safe, and inexpensive alternatives to standard suturing are desirable. Scalp lacerations are well suited for repair by staples. They implant rapidly and accurately even in the moving child. If only 1 or 2 are needed, one may omit the anesthetic injection. Cosmetic results are comparable to those of sutured repairs,[115] with no differences in complication and infection rates.[115,116] In pediatric scalp lacerations,[117] staples are 6 times faster than standard sutures and 8 times faster per cm. Their use results in decreases of approximately 30 to 40 % for costs of supplies and physician time.

Surgical tapes and tissue adhesives are painless alternatives to suture closure with no requirement for removal. An editorial in the plastic surgery literature comments that many facial lacerations are overtreated with sutures when skin tapes will suffice.[118] Unfortunately, the author provides no guidelines regarding eligible wound types. The cyanoacrylate adhesives are available outside of the United States and provide rapid closure.[119,120] Cosmetic results at 1 year are comparable to suture repair for small lacerations.[121] Initial strength is much less than with suture closure,[122] and wounds in regions of increased mobility or tension are incompatible with adhesive closure. By seven days, however, adhesive and suture repairs are comparable in strength.[123] Approval by the Food and Drug Administration is eagerly awaited, although unanswered concerns include interchangeability with tapes for small wounds under no tension, the inability to achieve adequate wound exploration and irrigation in the absence of local anesthetic, and the potential for misuse in inappropriate wounds.

Suture Techniques

Simple sutures and instrument ties. The standard technique for nearly all superficial sutures is the simple interrupted suture. For this and most other suture types, the needle is grasped with the tip of the needle holder approximately 1/3 of the distance from the swaged end to the point. Wound eversion is promoted by creation of a "pear" shape, in which the needle penetrates the skin perpendicular to its surface with the base of the loop at least as wide as the exposed portion. The width and the depth of the suture loop differ by anatomic location and should be similar to the thickness of the dermis.

Sutures are most efficiently completed with an instrument tie (Figure 2). The long (needle) end of the suture is wrapped around the jaws of the needle holder and the suture loop pulled closed after grasping the short (tail) end. Alternating directions of the wrap during subsequent throws completes a secure "square" knot. A common variation is the "surgeon's" knot, in which the first throw is wrapped twice around the needle holder. Although the completion of the knot and its final security are similar to the standard square knot, the surgeon's knot prevents slippage of the initial throw when tension separates the wound edges. Sutures should be tied only tightly enough to approximate the edges lightly, as excessive tension results in devascularization[124] and potentially increased scarring.

The number of sutures must be determined individually for each laceration, with consideration of skin tension and thickness, wound complexity, cosmesis and potential for infection. Ultimately, this number is as many as required to obtain closure with no gaps and with minimal tension, but as few as will suffice, since suture material will facilitate suppuration by a normally subinfective dose of bacteria.[69,109] As a rough guide is the distance between sutures is approximately the same as the width of the bite on one wound edge.[12]

Dermal sutures. A technically more difficult but indispensable technique, the dermal (buried) suture minimizes skin tension and permits early removal of percutaneous sutures, particularly in regions where suture marks are undesirable. This suture approximates the dermis just below the dermal-epidermal junction with an inverted profile, keeping the knot deep to prevent a visible deformity (Figure 3). Ideally, this suture fully approximates wound edges, leaving the final layer of percutaneous sutures to achieve further alignment without bearing tension. Although unlikely to result in complication on most facial wounds, this suture must used judiciously elsewhere, as the use of subcutaneous suture material increases the risk of infection, even when wounds are irrigated.[125,126]

Alternate suture types with specialized indications. The vertical mattress suture (Figure 4) is recommended for wounds under tension or with edges which tend to invert upon closure. By creating a deep and superficial loops of suture, this technique provides the near equivalent of 2 layers of closure, excludes wound margins from tension in suture loop, and provides excellent wound edge eversion. The traditional method begins with a wider bite taken in the standard fashion and concludes with a very narrow bite in a backhand fashion. An alternate technique starts with the narrow backhand bite and is more rapid, if there is no risk of blind penetration of deep structures.[127]

A horizontal mattress suture begins in the same manner as the simple interrupted suture, but continues with an additional bite in the opposite direction further along the wound edge. When completed, this suture resembles a purse string with 2 strands bridging the wound line subcutaneously. Although the suture everts wound edges and is less traumatic to the fragile skin found in elderly or steroid dependent patients, its pediatric indications are limited.

The half-buried horizontal mattress suture serves as a "corner" stitch for T- or Y-shaped flaps and stellate lacerations. Standard interrupted sutures may be difficult to place in the tip of a narrow flap and may cause vascular compromise. The subcutaneous course of this suture avoids these difficulties and pulls together several corners of a complex laceration (Figure 5). The depths of suture exit and entry and distances along opposing wound edges must be matched extremely carefully, and the technique may fail if there is difficulty in achieving alignment after 1 or 2 attempts as the traumatized tissue may be too friable to hold suture.

A running suture provides rapid closure of longer wounds, and is useful for children who cannot tolerate a time consuming closure (Figure 6). This technique evenly distributes tension along the wound line but may produce inconsistent eversion. Running closure is best reserved for wounds at low risk for infection with edges which align easily, since it does not permit easy revision during repair or selective suture removal in the event of infection.

In a running subcuticular suture, the suture material takes horizontal bites of the dermis on alternating sides of the wound without breaking the skin surface. Despite the theoretical advantages of avoiding cross marks and of creating a more water-tight seal, this technique does not reduce wound width when compared with percutaneous sutures[128] and may predispose to an increased rate of infection.[129]

Additional Considerations during Wound Repair

Delayed wound closure. Delayed closure is often advocated for "dirty" and late-presenting wounds. Traditional teaching dictates that the window of opportunity for successful primary repair is approximately 6 hours[130] based on the proliferation of wound flora and its relation to subsequent infection.[131]Aggressive wound toilet is conducted under local anesthesia at first presentation. The wound is left open under sterile dressings and repaired after a delay of 4 days.[132]

Despite its successful application for military wounds, the appropriate pediatric wound for this technique is not well defined. Wounds containing > 10^5 bacteria/gm of tissue are at increased risk for infection,[14] but bacterial quantitation is usually impractical. Furthermore, most pediatric wounds are not contaminated, and few pediatric patients present for care on a delayed basis. The few pediatric wounds presenting after 6 hours do not incur an increased risk of infection.[3] Experience in developing countries, moreover, suggests that delays up to 19 hours do not impede wound healing.[73] Wounds exceeding even 48 hours of age healed satisfactorily in 84 % of patients, with infection occurring in only 2.5 %. Head and neck wounds in this series were unaffected by delays. Arguably, although each wound's risk factors must be assessed individually, the inconvenience of delayed repair may outweigh the risk and potential consequences of a wound infection.

Repair of the "dog-ear." The dog-ear is a fold in a wound edge which cannot be matched to an equal length of skin along the opposite wound edge. In long wounds under tension or with asymmetric tissue loss, difficulty in aligning landmarks may produce this defect. Although dog-ears may be prevented by careful matching of landmarks or by serially bisecting the wound during suture placement, some become apparent only at the end of a lengthy repair. When suture removal and replacement is impractical, correction requires extension of the wound, angled toward the side of the deformity (Figure

6). This incision relaxes and flattens the fold in the wound edge, allowing the excess skin to be excised and the resulting flat skin defect to be sutured in the standard fashion.

Techniques for minimizing tension. Even without tissue loss, some wounds gape widely and close only with tension. Elimination of tension along the wound edges reduces the risk of wound dehiscence and formation of a widened scar. In clean wounds, the optimal method is by closure of the appropriate deep layers. Dermal sutures are particularly useful in relieving tension from the final percutaneous suture layer. The tension borne by the individual suture is reduced when distributed among a greater number of sutures placed closer together. Undermining is less likely to be useful as most pediatric wounds do not require advancement of skin over a significant tissue defect.

Specific Wound Types

Head and Neck

Head and neck wounds account for 60 to 81 % of pediatric lacerations.[2-4] The scalp is injured in 30 % and the face in 51 %, of which the majority are on the forehead with the chin a close second.[63] On the face, early suture removal (3-5 days) decreases the likelihood of suture marks and scar formation. Well placed dermal sutures achieve the initial alignment of major landmarks and minimize the tension borne by the percutaneous sutures.

The lip. Lip lacerations are closed according to the principles of facial closure elsewhere. Additional technical challenges are posed by vermilion border and through-and-through wounds. The final appearance of the vermilion border is assured by placement of an aligning suture through both edges of the divided vermilion border. This suture may be left untied while deeper muscle and dermal sutures are placed and tied when other percutaneous sutures are placed. Through-and-through lacerations are closed in layers as any other facial wound. A water tight seal is created first by closing the mucosa with an absorbable suture. Once isolated from oral secretions, the wound cavity is irrigated again and closed in layers.

Intraoral structures. Intraoral wounds occasionally prompt debate regarding the necessity for suture repair. Mucosal wounds which do not gape, interfere with function, or reveal underlying muscle lacerations heal well without sutures. Transverse tongue lacerations may be tolerated if there is no through-and-through penetration. Longitudinal lacerations at the tip of the tongue and gaping flaps on the side of the tongue should be repaired. Muscle is closed with absorbable synthetic suture. Several materials are useful for mucosal closure. Chromic gut is absorbed in a suitable time frame, but is often uncomfortable and may be removed inadvertently by the patient. Silk handles well and is comfortable *in situ* but provokes inflammation and requires a potentially painful removal. A useful compromise is a braided synthetic absorbable material, such as polygycolic acid or polyglactin 910, which combines strength and comfort with timely absorption.

The scalp. Most scalp wounds may be closed with a single layer of percutaneous sutures or staples. The blue color of polypropylene facilitates suture removal in dark-haired individuals. Defects in the galea or in the frontalis or occipitalis fascia may require separate closure with absorbable suture. An alternative closure technique for short scalp injuries is the "hair tie," in which strands of hair from opposite wound edges are twisted into short ropes and knotted together.[133]

Pitfalls. Most head and neck lacerations are uncomplicated, but specific pitfalls exist. Wounds through the medial portion of the eyelid may transect the lacrimal duct and those on the side of the face anterior to the ear may contain injuries to the facial nerve or parotid duct. Chin lacerations require careful examination to exclude mandible fractures.[134] Wounds to the neck should be assessed for violation of the platysma with potential injury to the underlying vital structures.

Extremities

Special considerations. The extremities are the second most frequently injured and account for a fifth of pediatric lacerations.[63] Closure is generally straightforward; however, the complex anatomy poses unique problems. All jewelry on the affected extremity should be removed in order to prevent complications resulting from edema and constriction. Deep sutures should be limited or avoided, particularly in the hand. Knowledge of the relevant anatomy facilitates assessment for possible vascular injury and sensory and motor deficits. Two-point discrimination should be 5 mm or less and is easily tested with a paper clip bent in the middle to expose the 2 pointed ends. The function of tendons which pass near the wound should be tested, but exploration through the anesthetized wound is necessary to reveal occult injuries such as incomplete tendon lacerations. Periarticular lacerations should arouse suspicion for joint penetration. A saline load test, also known as the saline arthrogram, should be considered, if clinical assessment is inconclusive.[135] Using a technique similar to that for diagnostic arthrocentesis, saline is injected to create a tense effusion. The addition of methylene blue to the injection assists in the identification of the joint injury. A positive test requires urgent consultation for possible operative debridement. The clenched fist injury is a common periarticular laceration, occurring over the metacarpophalangeal joint when the patient punches another individual's mouth. Even with a seemingly innocuous skin wound, this injury should be considered a human bite with potential joint penetration.

The fingertip injury. Distal phalangeal injuries are extremely frequent among toddlers whose fingers are trapped by closing doors. Clinical findings range from subungual hematoma to complete loss of distal skin coverage. A common intermediate outcome is laceration on one or both sides of the nail with varying degrees of traumatic nail avulsion. Traditional management involves removal of the nail followed by suture closure of the skin and nail bed lacerations.[136] The avulsed nail, or substitute fashioned from the sterile foil of a suture packet, is replaced in the nail fold to maintain its patency and to splint the injury. This aggressive approach is guided by the fear of a potential nail deformity. Even without a visible laceration, some authors argue that a subungual hematoma underlying more than 25 %[137] or 50 %[138] of the nail surface requires exploration for associated nail bed lacerations.

Evidence supporting such aggressive management is not uncontested. It is possible that occult subungual lacerations heal equally well or even better, if left undisturbed under the nail. The trephination of the nail by heated paper clip[139] or electrocautery[140] is quite satisfactory, leading to no complications or deformity. Excellent cosmetic outcomes also result from a conservative approach to more severe fingertip injuries.[141] The distal portion, usually a flap of skin and nailbed held by a thin volar pedicle, is held in place with surgical tapes without sutures or antibiotics. Even fingertip amputations distal to the distal interphalangeal joint regenerate rapidly, with or without exposed bone, when treated with serial outpatient dressing changes.[141,142] A prospective randomized trial comparing conservative and aggressive surgical approaches and their cosmetic and functional outcomes would provide welcome clarification.

Radiography of the lacerated distal phalanx is a common but questionable practice. This practice is reasonable if identification of fractures meaningfully alters management. However, simple distal phalangeal fractures, regardless of initial deformity, achieve reduction with alignment of the skin and nail bed, particularly if the nail is used as a splint. Indeed, I have never seen post-reduction radiographs obtained by clinicians who insist on the initial film. Although open fractures often require parenteral antibiotic therapy and operative debridement, their significance in the digits in controversial. One study reported an astonishing 30 % infection rate in untreated open distal phalangeal fractures compared with only 3 % among fractures treated with a variety of antibiotics.[143] However, this study's enrollment was highly skewed with only 10 patients in the untreated group. Furthermore, the lack of description of wound toilet and the inclusion of complex procedures such as grafts and V-Y flaps limit its applicability to the typical pediatric fingertip injury. A more believable rate of infection (8.7 %) occurred in untreated patients in a subsequent study,[144] which found no benefit from prophylactic antibiotics over aggressive wound care for open finger fractures. Of note, no patient in either series required treatment for osteomyelitis. A comparable situation exists with the trephination of subungual hematomas with underlying fractures, which results in no infections, despite the creation of a potential communication between the nail surface and the fracture.[140]

Torso

Much less common in children than head or extremity wounds, skin wounds of the thorax and abdomen can be treated according to the general principles of skin repair elsewhere. The primary concern with these wounds is identification of potential intrathoracic or intraabdominal penetration.

Bite Wounds

Bacteriology. Bite wounds raise concern over pathogens carried by the inflicting animal. In dog bites, *S. aureus* and *S. epidermidis* are more important pathogens than *Pasteurella multocida*.[145,146] The wound is more likely than a cat bite to be a tearing injury, which affects a greater amount of tissue but which is more amenable to wound toilet. Cat bites pose a greater risk of inoculation of *P. multocida* but have a low overall incidence of infection. In one series of cat bites,[147] puncture and extremity wounds were over-represented among infected wounds, but the true risk is unknown, because many patients do not seek care unless infection is already established. Human bites have the reputation of being "dirtier" than animal bites, largely because of complications experienced by adults from bites on the hands. Children appear to incur much less serious wounds with a low incidence of infection.[148]

Antibiotic prophylaxis. The common practice of providing antibiotic prophylaxis for all bites is controversial and poorly supported. Difficulties with animal bite studies include inconsistent definitions of infection, lack of standardized wound care, lack of randomization, inconsistent antibiotic choices, and inadequate sample size. A meta-analysis of the more scientifically sound studies demonstrated a statistically significant benefit of antibiotic prophylaxis in dog bites.[149] However, an accompanying editorial[150] commented that 100 patients would require treatment to prevent as few as 3.8 infections and suggests that antibiotic use be limited to higher risk wounds, such as bites to the hand. The rate of infections in cat bites is too low to demonstrate a significant benefit from prophylactic antibiotics.[147] Aggressive wound toilet, including debridement where appropriate[145] and careful examination for retained tooth fragments, is more likely to influence outcome. Suturing of low-risk, cosmetically sensitive regions such as the face is unlikely to increase the risk of infection.[145]

These findings lead to the recommendation to reserve antibiotic use for patients with compromised immunity, wounds of the distal extremities, deep puncture wounds not amenable to wound toilet, and wounds at risk for injury to underlying structures (joint, tendon).[151,152] Wounds of the face and scalp, although at risk for cranial penetration in small infants bitten by large animals, are at low risk for infection. Antibiotics, if used, may need to be administered early to be effective,[153] and should include gram positive coverage (dicloxacillin, cephalexin, erythromycin) for all treated bites and additional consideration of *Pasteurella* (penicillin, amoxicillin) for cat bites. Coverage for high-risk (clenched fist) or infected human bite wounds should include activity against *Eikenella corrodens* (penicillin).

The common recommendation for amoxicillin-clavulanate[154] is based on studies of animal oral flora[155] and of established wound infections,[156] which raise concern over polymicrobial infection with *P. multocida* , anaerobes, and *Staphylococcus* species. Although amoxicillin-clavulanate provides the broadest single-drug coverage, prophylaxis against all potential or proven pathogens may be unnecessary. In clinical trials, the drug has only been studied against placebo[157] or "penicillin ±

dicloxacillin,"[158] and its superiority over cheaper alternatives with fewer adverse effects has not been demonstrated. In one series of dog bites, 95 % of established infections were treated successfully with a first generation cephalosporin.[146]

Vaccination. Rabies exposure is a frequent concern of patients and parents presenting for care of animal bites. The decision to initiate postexposure prophylaxis[159] should be dictated by knowledge of regional rabies carriage in the biting species and the ability to monitor the implicated animal. Tetanus status is addressed as with all wounds.

Foreign Bodies

Wounds caused by penetrating objects or incurred in the presence of particulate matter may harbor a foreign body. Many are radio-opaque, including glass,[13] and their retrieval may be facilitated by the use of surface markers at the entry site such as a standard paper staple bent into the shape of an arrowhead. A more invasive and cumbersome but potentially more accurate localization involves several small gauge needles placed at various location to different depths in the skin surrounding the suspected foreign body.

Foreign bodies close to the skin wound or localized by a surface marker may be retrieved by probing through the wound or a well placed incision. However, the anticipated ease of removal is often deceptive, and the temptation to persist at prolonged attempts is great. Therefore, time limits should be established and strictly observed. Beyond that point, the patient should be referred for removal with more advanced techniques or for consideration of non-operative observation.

Traumatic amputations

Although most clinicians do not provide definitive care of the traumatic amputation, correct initial management may increase the likelihood of a successful replantation.[12] Despite the dramatic and emotion-provoking nature of the injury, the first priority is proximal to the amputation, with attention to cardiorespiratory stability and control of hemorrhage. The amputated part is wrapped in dry or minimally moistened sterile gauze and placed in a plastic bag, which is surrounded by ice and water during transport. Viability is decreased by saturation of the amputated part or by storage on ice without water or on dry ice.

Aftercare

Wound Dressings

Occlusive dressings are touted for their ability to promote re-epithelialization. Water tight materials such as polyurethane films (Opsite, Tegaderm) are convenient for burns and promote rapid healing with a one-time application.[160,161] However, they retain copious amounts of exudate during early wound healing and may cause inadvertent de-epithelialization if removed prematurely. A dressing consisting of petrolatum impregnated mesh covered with dry gauze provides similar protection but draws exudate into a layer which can be replaced without disturbing the underlying wound.[162] Such layered dressings are most useful for coverage of burns and abrasions and for the initial protection of large sutured lacerations. However, for regions of minor skin loss or small sutured wounds, a frequently applied antibiotic ointment may be more practical, and reduces the incidence of infection when compared with placebo.[163] Standard adhesive bandages (Band-Aid) combined with an antibiotic ointment provided healing and protection similar to the newer semiocclusive dressing materials for skin biopsy sites,[164] and are likely to perform as well for minor wounds. Sun protection may prevent abnormal pigmentation,[165] but the true benefit and duration of treatment are not well defined.

Parents frequently inquire about treatments outside of the realm of standard wound aftercare. Aloe vera gel incorporated into dressing materials is associated with more rapid healing of dermabrasion wounds.[166] However, the preparation of the gel, its applicability to traumatic wounds and the long-term cosmetic benefit are unclear. Similarly, little scientific information is available on the role of vitamin E in wound healing. Oral vitamin E is associated with minor improvement in the early healing of a subset of patients with chronic ulcers,[167] but long term benefit is not clear. Topical vitamin E provides no functional or cosmetic benefit following post-burn reconstructive surgery.[168] If a patient's family is motivated to apply these agents, no harm is likely to result, but little guidance on use, duration or expected outcome exists.

Immobilization

For wounds in regions subject to considerable movement, the necessity and duration of immobilization are not always clearly defined. However, it is probably most prudent to immobilize at least briefly the repaired wounds of active young children. A bulky dressing for common hand and digit injuries is fashioned by layering rolled gauze over the dorsal and volar aspects of the hand and wrist and between the fingers. When completed with a circumferential layer, the resultant mitten or boxing glove separates and immobilizes the fingers, protects the repair and absorbs wound exudate. More prolonged and rigid immobilization is provided by plaster or fiberglass splints or from commercially available devices such as knee immobilizers.

Tetanus Prophylaxis

Most children receiving routine well child care and attending school are in compliance with recommended vaccination schedules. However, school age and adolescent patients may easily be considered "up to date" yet lack a recent tetanus booster. Current guidelines state that tetanus toxoid may be deferred in patients with "clean, minor" wounds who have completed a primary series or received a booster dose within 10 years. However, for any patient over 10 years of age, a wound care encounter is an ideal opportunity to review tetanus status and to offer a booster dose if the family is not certain of tetanus toxoid administration within 5 years. The rare case of highly contaminated wounds and patients with incomplete vaccinations is discussed elsewhere.[169]

Antibiotics

Wound infections occur in 1.2 to 3 %[3,170,171] of all sutured wounds, with increased risk associated with bites, the extremities (especially lower) and complex or long (> 3-5 cm) wounds. Although pre-incision antibiotic prophylaxis decreases the incidence of wound infection in elective surgery,[172] the contamination of traumatic wounds occurs long before the opportunity for antibiotic administration. Antibiotic prophylaxis left to the discretion of the individual physician is associated with a fourfold increase in infections,[3] likely the result of a tendency to prescribe when the risk of infection is already high. However, studies which randomize antibiotic use also demonstrate no benefit, and possibly a greater incidence of infection, in treated patients.[125,149] Even the hand, usually thought to be at greater risk, shows no greater tendency to infection if treated with meticulous wound care without antibiotics.[173] Prophylaxis of intraoral wounds is less certain, although one study equivocally suggests that penicillin may decrease the incidence of infection in through-and-through wounds.[174] When antibiotic prophylaxis is desired, administration within several hours of wounding is recommended, although measures to disrupt the wound coagulum may prolong the period of effectiveness.[153,175] The animal experiments which define a limited period of antibiotic effectiveness omit standard wound care and may not apply to the average human wound. Nonetheless, antibiotic administration at the time of wound care results in fewer delays than writing a prescription after the repair is complete. Duration of treatment is not well studied; however, I am unaware of any data demonstrating any benefit of prophylaxis for longer than 3 days.

Wound Hygiene

The clichéd instruction to "keep it clean and dry" is contradictory if not impossible. Avoidance of contact with water, especially with unchanged dressings, leaves a crusted, filthy wound and skin maceration, resulting in difficulty with suture removal. Initial epithelialization is likely to have occurred by 24 hours, and lacerations washed as early as 8 to 24 hours after repair heal as well as those which remain dry.[176] Other activities such as swimming have not been studied, and differences from daily showering are likely to be more important than the similarities. Prolonged immersion, inadvertent trauma to the wound, and potential bacterial contamination of swimming pools or other bodies of water pose unknown risks to the healing wound. Although no formal guidelines exist, it is probably safest to avoid swimming until the skin integrity is established following suture removal.

In dependable patients with clean wounds, a wound check appointment may not be required if parents can be taught the clinical signs which mandate re-evaluation. With infection-prone wounds or unreliable families, a return visit within 2 days may be warranted, as patients may prove inaccurate in the self-diagnosis of wounds infections.[177]

Specialty Consultation

Parents occasionally inquire into the services of a plastic surgeon with the expectation of a cosmetic advantage. In my opinion, few lacerations seen in routine practice are beyond the scope of the primary care clinician with an interest and a moderate amount of experience in wound repair. More often, time constraints and the need for sedation or general anesthesia, rather than technical difficulty, are the limiting factors. When parents request a plastic surgeon for wounds comfortably within my capacity, I advise them that such consultation provides no expected difference in the repair technique or cosmetic outcome. Scar formation is an inevitable consequence of wound healing and is determined as much by patient and wound physiology as by the credentials of the operator. Because the ultimate appearance of any scar is not known for 6 months or longer, delayed referral for eventual scar revision can occur at a later date. However, for parents who insist upon referral for initial repair, it occasionally prudent to accede to this demand in order to preserve the patient-physician relationship.

Approach to the Fearful or Uncooperative Child

Avoiding Unnecessary Sedation

A common concern regarding pediatric procedures is the need for control of behavior. Surgical consultants, accustomed to the luxury of general anesthesia, often insist on potent pharmacologic measures. However, most procedures are readily accomplished without resorting to medications. Certainly, there is no ideal sedative agent, and none is without risk. A poll of children's hospital EDs[178] found that an alarming 28 % of respondents would not use their institution's primary sedative agent on their own children. Based on personal observation, I have identified 10 common errors in wound repair which compound difficult behavioral situations.

1. *Fail to address the patient.* Confining one's attention to the parents may appear to be more efficient but may make the child feel helpless and alienated. Letting the child provide some of the wound history is a practical means of establishing a rapport. From that point, an ongoing banter can have a significant calming effect. Suggestible children of school age can be drawn into a conversation so deeply as to have a nearly analgesic effect.

2. *Send the parents from the room*. Clinical experience and surveys [179,180] of parents and personnel indicate that, at least for minor procedures, parental presence is desirable and probably beneficial. The majority of parents surveyed wanted to watch (not merely be present), and many felt that it would help themselves, the child *and* the physician. [179] Nonetheless, tactful judgment is important to minimize the counterproductive effect of the parent who faints or the parent who provokes anxiety or facilitates escalation of adverse behaviors.

3. *Fail to use the parents as an ally*. Parental presence can work to the clinician's favor. Simply being in the line of sight can be quite reassuring. The parent who can keep a child engaged with favorite stories or other conversation can be much more effective than any medication.

#4. *Fail to have everything ready*. A flurry of disorganized activity is anxiety-provoking to a patient already dreading a procedure. Even highly organized clinicians should consider preparing suture supplies outside of the patient's room.

5. *Cover the child's face*. There is almost no reason to drape more than one side of the wound. The claustrophobia of drapes and the loss of eye contact with the parent is a near certain way to lose cooperation.

6. *Let the child watch the preparation of syringe and needle*. Without deceiving the child about the eventual injection, it is useful to keep one's back turned while drawing up medication, to handle the syringe below the level of the exam table, and to tuck the syringe below a drape until needed.

7. *Inject large amounts of lidocaine quickly*. Techniques to reduce the pain of injection are discussed above.

8. *Promise the child no pain*. Parents often offer this reassurance, which is a promise the clinician cannot keep. If unexpected pain occurs, the child will be mistrustful and may fight through the procedure even after full anesthesia occurs.

9. *Use the parents to restrain the child*. This is the role of the “bad guy” and should be assigned to the clinical staff. The unwilling parent-recruit resents the staff, and the child resents the parent, resulting in ineffective restraint. A papoose board is a most effective adjunct, since most lacerations occur on the face and scalp. The digits are also commonly injured, and an IV armboard with ties provides flexible and effective extremity immobilization.

10. *Let the suspense build up*. A procedure that flows smoothly prevents anxiety. Older children and adolescents may benefit from strategic delay and tactful negotiation. However, toddlers and uncooperative younger children will not be so persuaded. For these patients, all segments of a laceration repair that can be perceived as an assault should be collapsed into one. Thus, by the time the child

recovers from the indignation of being restrained, the clinician may have already completed anesthesia and irrigation and can begin suturing with relative ease.

Use and monitoring of pharmacologic agents

For children who require sedation, many agents exist, each providing a different combination of clinical effects. Although none occurs in isolation, four different clinical effects are of interest. For older patients, *anxiolysis* may suffice. However, younger patients may need a specific *sedative* effect to prevent excessive movement. *Amnesia* is useful for any potentially distressing procedure. On the other hand, systemic *analgesia* is less important if local anesthesia is effective.

More important to patient safety is the depth of sedative effect, commonly divided into three levels: conscious, in which airway patency and protective reflexes are maintained and the patient responds to a light stimulus; deep, in which there is potential loss of reflexes or airway patency and the patient may not be easily aroused; and general anesthesia. Ideally, the patient should be consciously sedated only to the extent necessary to perform the procedure. Unfortunately, no drug combines all the desired effects with freedom from adverse effects. Furthermore, there is no way to predict what level of sedation will be reached or if the patient will slip into a deeper level.

Therefore, sedation guidelines have been published[181,182] and include capacity for: continuous clinical and electronic monitoring; airway and respiratory support; and full resuscitation. Any clinician contemplating the use of sedation for procedures should be familiar with these documents as well as with the literature pertaining to all sedative and reversal agents involved. Sedation must occur in a facility where personnel are familiar with a written policy consistent with these recommendations.

The pre-sedation evaluation focuses on the possibility of adverse events and includes consideration of: last oral intake; medications, allergies, and adverse drug history; co-morbidity; personal and family experience with sedation and anesthesia; and the general physical examination including airway patency and neck mobility. Full preparedness includes ability to intubate the trachea or to support the airway by other means until definitive treatment is available. The informed consent process should include documentation of a discussion of the likely risks, benefits and alternatives to the wound repair and sedation as well as the parents' comprehension and willingness to proceed.

The published guidelines do not specify fasting times for wound sedation.[181,182] However, it is reasonable to allow clear liquids 2 hours[183] and solid foods 3 to 4 hours prior to sedation, although data are lacking regarding the latter. With significant trauma or acute abdominal conditions, the duration of fasting may not predict the state of gastric emptying. If safe fasting conditions cannot be assured, one should consider delaying the sedated procedure or proceeding without sedation.

Monitoring includes at least continuous pulse oximetry, ideally in conjunction with cardiac monitoring, with vital signs and oxyhemoglobin saturation recorded on a frequent basis. The guidelines recommend the presence of an additional appropriately trained person whose sole responsibility is to monitor the patient's stability. Safe discharge criteria include: ongoing cardiorespiratory stability; rousability with intact reflexes; return of normal speech; and ability to sit unassisted and ambulate with minimal assistance (or as close to baseline as possible). Although patients need not consume liquids before discharge,[184] they should not be vomiting or at risk for dehydration.

Selected Sedative Agents

Midazolam has been described as coming the "closest of any sedative to producing a true state of conscious sedation in children,"[185] and its properties of safety, anxiolysis, amnesia, rapidity of action, and pharmacologic reversibility make it exremely useful as long as pain control is accomplished by other means. Intravenous administration (0.5-1 mg/kg increments) permits rapid titration and elimination, resulting in brief recovery times. Respiratory depression is rare unless combined with other drugs.[186] The drug is also effective by the oral,[187,188] intranasal,[188,189] and rectal[190] routes, although oral administration results in decreased bioavailability and delayed onset due to "first pass" hepatic metabolism. Intranasal administration is highly effective but quite irritating,[188,191] and the drug may be better tolerated rectally by younger patients and sublingually[191] by older patients developmentally able to cooperate. Disinhibitory responses may occur and lead to agitation which persists or begins after the procedure is completed.[190]

Successful use of fentanyl for pediatric wound repair has been reported.[192] Like midazolam, IV titration (1 µg/kg increments) and elimination are rapid. As an opioid, it is a potent analgesic, and sedation is a secondary effect. Fentanyl, given transmucosally (10-20 µg/kg) in a "sweetened matrix in lozenge form on a holder" (lollipop), provides sedation in a non-threatening manner.[193] Although effective, it causes a frequency of vomiting not seen with intravenous use. A major concern, as with all drugs of its class, is respiratory depression, especially in combination with other drugs. A common minor annoyance is facial pruritis.

Fentanyl and midazolam together result in a remarkable combination of sedation, analgesia and amnesia. Clinically inapparent oxyhemoglobin desaturation occurs relatively frequently with routine doses,[186] and more aggressive dosing may result in profound respiratory depression.[194] The effect is more profound than needed for most lacerations, and the combination is best reserved it for refractory patients or for more drastic procedures such as fracture reduction.

Nitrous oxide (N_2O) is extremely rapid acting and provides sedation, analgesia and amnesia. Self-administration by older children is ideal because of the autoregulation which results when the patient becomes too drowsy to hold the mask. Recently, however, 50 % N_2O was also found to be effective for laceration repair in children as young as 2 years of age.[195] The major limitation to its utility is the expense of the required regulator and scavenging system.

Ketamine (2-4 mg/kg IM)[196,197] is a dissociative drug which profoundly suppresses voluntary resistance to procedures while maintaining respiratory drive and cardiovascular tone. The behavioral effects may be disturbing to parents and often necessitate time- and labor-intensive monitoring in an isolated room. Thus, the drug is best suited for the most difficult of procedures such as tongue and perineal injuries in highly uncooperative children. Adverse effects including copious salivation, laryngospasm, and apnea. Co-administration with atropine may minimize secretions. Midazolam may temper the emergence phenomena but prolongs recovery times.

The combination of meperidine and hydroxyzine (1-2 mg and 0.5-1 mg per kg, respectively) may be less optimal than more rapid acting alternatives but is more readily available in most practice settings. The potent mix of analgesia and sedation is compatible in a single intramuscular injection. In many cases, however, there may be more opioid effect and longer duration than most patients need, and the normeperidine metabolite may provoke seizures.

The so-called DPT cocktail (meperidine, promethazine, chlorpromazine) merits mention because of its adverse effects and disadvantages.[198] The combination is not pharmacologically rational and predisposes to the risk of hypotension, respiratory depression and seizures. In addition, recovery times are exceedingly long. The safest recommendation would be to avoid this regimen.

Summary

Lacerations are a frequent reason for pediatric health care visits. Many are referred to EDs or to surgical specialists but may be treated by the pediatrician with the time and interest in maintaining wound care skills. Although skin closure is often viewed as the primary event in wound care, local anesthesia and wound toilet are equally important aspects in which expertise is often undervalued. On occasion, patient anxiety and resistance complicates wound care, and a variety of sedative techniques facilitates completion of procedures which otherwise would require general anesthesia. Adherence to basic principles and the occasional use of innovations in wound care enable the clinician to bring about optimal outcomes.

REFERENCES

1. Krauss BS, Harakal T, Fleisher GR. The spectrum and frequency of illness presenting to a pediatric emergency department. Pediatr Emerg Care 1991;7:67-71.
2. Nelson DS, Walsh K, Fleisher GR. Spectrum and frequency of pediatric illness presenting to a general community hospital emergency department. Pediatrics 1992;90:5-10.
3. Baker MD, Lanuti M. The management and outcome of lacerations in urban children. Ann Emerg Med 1990;19:1001-1005.
4. Smith GA, Strausbaugh SD, Harbeck-Weber C, Cohen DM, Shields BJ, Powers JD. New non-cocaine-containing topical anesthetics compared with tetracaine-adrenaline-cocaine during repair of lacerations. Pediatrics 1997;100:825-830.
5. Berk WA, Welch RD, Bock BF. Controversial issues in clinical management of the simple wound. Ann Emerg Med 1992;21:72-80.
6. Howell JM, Chisholm CD. Outpatient wound preparation and care: a national survey. Ann Emerg Med 1992;21:976-981.
7. Fein JA, Lavelle J, Giardino AP. Teaching emergency medicine to pediatric residents: a national survey and proposed model. Pediatr Emerg Care 1995;11:208-211.
8. Del Beccaro MA, Shugerman RP. Pediatric residents in the emergency department: what is their experience? Ann Emerg Med 1998;31:49-53.
9. Cardany CR, Rodeheaver G, Thacker J, Edgerton MT, Edlich RF. The crush injury: a high risk wound. JACEP 1976;5:965-970.
10. Cruse PJE, Foord R. A five-year prospective study of 23,649 surgical wounds. Arch Surg 1973;107:206-210.
11. Hollander JE, Singer AJ, Valentine S. Comparison of wound care practices in pediatric and adult lacerations repaired in the emergency department. Pediatr Emerg Care 1998;14:15-18.
12. Trott A. Wounds and lacerations: emergency care and closure. 2nd ed. St. Louis: Mosby-Year Book, Inc.; 1997.
13. Tandberg D. Glass in the hand and foot: Will an x-ray film show it? JAMA 1982;248:1872-1874.

14. Courter BJ. Radiographic screening for glass foreign bodies--what does a "negative" foreign body series really mean? Ann Emerg Med 1990;19:997-1000.

15. Mofenson HC, Caraccio TR, Miller H, Greensher J. Lidocaine toxicity from topical mucosal application. Clin Pediatr (Phila) 1983;22:190-192.

16. Alfano SN, Leicht MJ, Skiendzielewski JJ. Lidocaine toxicity following subcutaneous administration. Ann Emerg Med 1984;13:465-467.

17. Grimes DA, Cates W. Deaths from paracervical anesthesia used for first-trimester abortion, 1972-1975. N Engl J Med 1976;295:1397-1399.

18. Fariss BL, Foresman PA, Rodeheaver GT, Chang DE, Smith JF, Morgan RF, et al. Anesthetic properties and toxicity of bupivacaine and lidocaine for infiltration anesthesia. J Emerg Med 1987;5:275-282.

19. Spivey WH, McNamara RM, MacKenzie RS, Bhat S, Burdick WP. A clinical comparison of lidocaine and bupivacaine. Ann Emerg Med 1987;16:752-757.

20. de Jong RH, Bonin JD. Mixtures of local anesthetics are no more toxic than the parent drugs. Anesthesiology 1981;54:177-181.

21. Sweet PT, Magee DA, Holland AJC. Duration of intradermal anaesthesia with mixtures of bupivacaine and lidocaine. Can Anaesth Soc J 1982;29:481-483.

22. Ribotsky BM, Berkowitz KD, Montague JR. Local anesthetics: Is there an advantage to mixing solutions? J Am Podiatr Med Association 1996;86:487-491.

23. Hernandez PA, Lubitz JJ, Steinhart AN. Lidocaine and bupivacaine: Is a mixture effective? J Am Podiatry Assoc 1983;73:510-513.

24. Bromage PR, Gertel M. Improved brachial plexus blockade with bupivacaine hydrochoride and carbonated lidocaine. Anesthesiology 1972;36:479-487.

25. Cunningham NL, Kaplan JA. A rapid-onset, long-acting regional anesthetic technique. Anesthesiology 1974;41:509-511.

26. Swanson JG. Assessment of allergy to local anesthetic. Ann Emerg Med 1983;12:316-318.

27. Ernst AA, Marvez-Valls E, Mall G, Patterson J, Xie X, Weiss SJ. 1 % lidocaine versus 0.5 % diphenhydramine for local anesthesia in minor laceration repair. Ann Emerg Med 1994;23:1328-1332.

28. Todd K, Berk WA, Huang R. Effect of body locale and addition of epinephrine on the duration of action of a local anesthetic agent. Ann Emerg Med 1992;21:723-726.

29. Christoph RA, Buchanan L, Begalia K, Schwartz S. Pain reduction in local anesthetic administration through pH buffering. Ann Emerg Med 1988;17:117-120.

30. Bartfield JM, Ford DT, Homer PJ. Buffered versus plain lidocaine for digital nerve blocks. Ann Emerg Med 1993;22:216-219.

31. Bartfield JM, Gennis P, Barbera J, Breuer B, Gallagher EJ. Buffered versus plain lidocaine as a local anesthetic for simple laceraion repair. Ann Emerg Med 1990;19:1387-1389.

32. McKay W, Morris R, Mushlin P. Sodium bicarbonate attenuates pain on skin infiltration with lidocaine, with or without epinephrine. Anesth Analg 1987;66:572-574.

33. Brogan GX, Singer AJ, Valentine SM, Thode HC, Giarrusso E, Hollander JE. Comparison of wound infection rates using plain versus buffered lidocaine for anesthesia of traumatic wounds. Am J Emerg Med 1997;15:25-28.

34. Palmon SC, Lloyd AT, Kirsch JR. The effect of needle gauge and lidocaine pH on pain during intradermal injection. Anesth Analg 1998;86:379-381.

35. Bartfield JM, Homer PJ, Ford DT, Sternklar P. Buffered lidocaine as a local anesthetic: an investigation of shelf life. Ann Emerg Med 1992;21:16-19.

36. Stewart JH, Chinn SE, Cole GW, Klein JA. Neutralized lidocaine with epinephrine for local anesthesia--II. J Dermatol Surg Oncol 1990;16:842-845.

37. Stewart JH, Cole GW, Klein JA. Neutralized lidocaine with epinephrine for local anesthesia. J Dermatol Surg Oncol 1989;15:1081-1083.

38. Mader TJ, Playe SJ, Garb JL. Reducing the pain of local anesthetic infiltration: Warming and buffering have a synergistic effect. Ann Emerg Med 1994;23:550-554.

39. Waldbillig DK, Quinn JV, Stiell IG, Wells G. Randomized double-blind controlled trial comparing room-temperature and heated lidocaine for digital nerve block. Ann Emerg Med 1995;26:677-681.

40. Arndt KA, Burton C, Noe JM. Minimizing the pain of local anesthesia. Plast Reconstr Surg 1983;72:676-679.

41. Krause RS, Moscati R, Filice M, Lerner B, Hughes D. The effect of injection speed on the pain of lidocaine infiltration. Acad Emerg Med 1997;4:1032-1035.

42. Scarfone RJ, Jasani M, Gracely EJ. Pain of local anesthetics: rate of administration and buffering. Ann Emerg Med 1998;31:36-40.

43. Adamson S, Menegazzi JJ, Paris PM, Kurtek RW. A randomized, controlled trial of the effectiveness of counterirritation on venipuncture-associated pain (abstract). Acad Emerg Med 1997;4:425.

44. Kelly AM, Cohen M, Richards D. Minimizing the pain of local infiltration anesthesia for wounds by injection into the wound edges. J Emerg Med 1994;12:593-595.

45. Bartfield JM, Sokaris SJ, Raccio-Robak N. Local anesthesia for lacerations: pain of infiltration inside vs outside the wound. Acad Emerg Med 1998;5:100-104.

46. Murphy MF. Regional anesthesia in the emergency department. Emerg Med Clin North Am 1988;6:783-810.

47. Lynch MT, Syverud SA, Schwab RA, Jenkins JM, Edlich R. Comparison of intraoral and percutaneous approaches for infraorbital nerve block. Acad Emerg Med 1994;1:514-519.

48. Syverud SA, Jenkins JM, Schwab RA, Lynch MT, Knoop K, Trott A. A comparative study of the percutaneous versus intraoral technique for mental nerve block. Acad Emerg Med 1994;1:509-513.

49. Bartfield JM, Raccio-Robak N, Salluzzo RF. Does topical lidocaine attenuate the pain of infiltration of buffered lidocaine? Acad Emerg Med 1995;2:104-108.

50. Bartfield JM, Lee FS, Raccio-Robak N, Salluzzo RF, Asher SL. Topical tetracaine attenuates the pain of infiltration of buffered lidocaine. Acad Emerg Med 1996;3:1001-1005.

51. Hegenbarth MA, Altieri MF, Hawk WH, Ochsenschlager DW, O'Donnell R. Comparison of topical tetracaine, adrenaline, and cocaine anesthesia with lidocaine infiltration for repair of lacerations in children. Ann Emerg Med 1990;19:63-67.

52. Terndrup TE, Walls HC, Mariani PJ, Gavula DP, Madden CM, Cantor RM. Plasma cocaine and tetracaine levels following application of topical anesthesia in children. Ann Emerg Med 1992;21:162-166.

53. Bonadio WA. TAC: a review. Pediatr Emerg Care 1989;5:128-130.

54. Dronen SC. Complications of TAC (letter). Ann Emerg Med 1983;12:333.

55. Bonadio WA, Wagner V. Letter to editor. Pediatr Emerg Care 1988;4:229-230.

56. Wehner D, Hamilton GC. Seizures following topical application of local anesthetics to burn patients. Ann Emerg Med 1984;13:456-458.

57. Daya MR, Burton BT, Schleiss MR, DiLiberti JH. Recurrent seizures following mucosal application of TAC. Ann Emerg Med 1988;17:646-648.

58. Dailey RH. Fatality secondary to misuse of TAC solution. Ann Emerg Med 1988;17:159-160.

59. Bonadio WA. Safe and effective method for application of tetracaine, adrenaline and cocaine to oral lacerations. Ann Emerg Med 1996;27:396-398.

60. Ernst AA, Marvez-Valls E, Nick TG, Weiss SJ. LAT (lidocaine-adrenaline-tetracaine) versus TAC (tetracaine-adrenaline-cocaine) for topical anesthesia in face and scalp lacerations. Am J Emerg Med 1995;13:151-154.

61. Ernst AA, Marvez E, Nick TG, Chin E, Wood E, Gonzaba WT. Lidocaine adrenaline tetracaine gel versus tetracaine adrenaline cocaine gel for topical anesthesia in linear scalp and facial lacerations in children aged 5 to 17 years. Pediatrics 1995;95:255-258.

62. Schilling CG, Bank DE, Borchert BA, Klatzko MD, Uden DL. Tetracaine, epinephrine (adrenalin), and cocaine (TAC) versus lidocaine, epinephrine and tetracaine (LET) for anesthesia of lacerations in children. Ann Emerg Med 1995;25:203-208.

63. Smith GA, Strausbaugh SD, Harbeck-Weber C, Shields BJ, Powers JD, Hackenberg D. Comparison of topical anesthetics without cocaine to tetracaine-adrenaline-cocaine and lidocaine

infiltration during repair of lacerations: Bupivacaine-norepinephrine is an effective new topical anesthetic agent. Pediatrics 1996;97:301-307.

64. Halperin DL, Koren G, Attias D, Pellegrini E, Greenberg ML, Wyss M. Topical skin anesthesia for venous, subcutaneous drug reservoir and lumbar punctures in children. Pediatrics 1989;84:281-284.

65. Taddio A, Stevens B, Craig K, Rastogi P, Ben-David S, Shennan A, et al. Efficacy and safety of lidocaine-prilocaine cream for pain during circumcision. N Engl J Med 1997;336:1197-1201.

66. Zempsky WT, Karasic RB. EMLA versus TAC for topical anesthesia of extremity wounds in children. Ann Emerg Med 1997;30:163-166.

67. Powell DM, Rodeheaver GT, Foresman PA, Hankins CL, Bellian KT, Zimmer CA, et al. Damage to tissue defenses by EMLA cream. J Emerg Med 1991;9:205-209.

68. Kumar AR, Dunn N, Naqvi M. Methemoglobinemia associated with a prilocaine-lidocaine cream. Clin Pediatr (Phila) 1997;36:239-240.

69. Elek SD. Experimental staphylococcal infections in the skin of man. Ann N Y Acad Sci 1956;65:85-90.

70. Robson MC. Disturbances of wound healing. Ann Emerg Med 1988;17:1274-1278.

71. Bodiwala GG, George TK. Surgical gloves during wound repair in the accident-and-emergency department. Lancet 1982;2:91-92.

72. Maitra AK, Adams JC. Use of sterile gloves in the management of sutured hand wounds in the A&E department. Injury 1986;17:193-195.

73. Berk W, Osbourne DD, Taylor DD. Evaluation of the "golden period" for wound repair: 204 cases from a third world emergency department. Ann Emerg Med 1988;17:496-500.

74. Caliendo JE. Surgical masks during laceration repair. JACEP 1976;278:278-279.

75. Lammers RL, Fourre M, Callaham ML, Boone T. Effect of povidone-iodine and saline soaking on bacterial counts in acute, traumatic contaminated wounds. Ann Emerg Med 1990;19:709-714.

76. Faddis D, Daniel D, Boyer J. Tissue toxicity of antiseptic solutions: a study of rabbit articular and periarticular tissues. J Trauma 1977;17:895-897.

77. Rodeheaver G, Bellamy W, Kody M, Spatafora G, Fitton L, Leyden K, et al. Bactericidal activity and toxicity of iodine-containing solutions in wounds. Arch Surg 1982;117:181-186.

78. Brånemark PI, Ekholm R, Altrektsson B, Lindström J, Lundborg G, Lundskog J. Tissue injury caused by wound disinfectants. J Bone Joint Surg Am 1967;49-A:48-62.

79. Schneider DL, Hebert LJ. Subcutaneous gas from hydrogen peroxide administration under pressure. Am J Dis Child 1987;141:10-11.

80. Swayne LC, Ginsber HN, Ginsburg A. Pneumoretroperitoneum secondary to hydrogen peroxide wound irrigations. AJR Am J Roentgenol 1987;148:149-150.

81. Bryant CA, Rodeheaver GT, Reem EM, Nichter LS, Kenney JG, Edlich RF. Search for a nontoxic surgical scrub solution for periorbital lacerations. Ann Emerg Med 1984;13:317-321.

82. Custer J, Edlich RF, Prusak M, Madden J, Panek P, Wangensteen OH. Studies in the mangement of the contaminated wound: V. An assessment of the effectiveness of pHisoHex and betadine surgical scrub solutions. Am J Surg 1971;121:572-575.

83. Oberg MS, Lindsey D. Do not put hydrogen peroxide or povidone iodine into wounds! Am J Dis Child 1987;141:27-28.

84. Lineaweaver W, Howard R, Soucy D, McMorris S, Freeman J, Crain C, et al. Topical antimicrobial toxicity. Arch Surg 1985;120:267-270.

85. Edlich RF, Custer J, Madden J, Dajani A, Rogers W, Wangensteen OH. Studies in management of the contaminated wound: III. Assessment of the effectiveness of irrigation with antiseptic agents. Am J Surg 1969;118:21-29.

86. Mulliken JB, Healey NA, Glowacki J. Povidone-iodine and tensile strenth of wounds in rats. J Trauma 1980;20:323-324.

87. Gilmore OJA, Reid C, Strokon A. A study of the effect of povidone-iodine on wound healing. Postgrad Med J 1977;53:122-125.

88. Gravett A, Sterner S, Clinton JE, Ruiz E. A trial of povidone-iodine in the prevention of infection in sutured lacerations. Ann Emerg Med 1987;16:167-171.

89. Viljanto J. Disinfection of surgical wounds without inhibition of normal wound healing. Arch Surg 1980;115:253-256.

90. Rodeheaver GT, Smith SL, Thacker JG, Edgerton MT, Edlich RF. Mechanical cleansing of contaminated wounds with a surfactant. Am J Surg 1975;129:241-245.

91. Rodeheaver G, Kurtz L, Kircher BJ, Edlich R. Pluronic F-68: A promising new skin wound cleanser. Ann Emerg Med 1980;9:572-576.

92. Chanoine JP, Boulvain M, Bourdoux P, Pardou A, Van Thi HV, Ermans AM, et al. Increased recall rate at screening for congenital hypothyroidism in breast fed infants born to iodine overloaded mothers. Arch Dis Child 1988;63:1207-1210.

93. Linder N, Davidovitch N, Reichman B, Kuint J, Lubin D, Meyerovitch J, et al. Topical iodine-containing antiseptics and subclinical hypothyroidism in preterm infants. J Pediatr 1997;131:434-439.

94. Seropian R, Reynolds BM. Wound infections after preoperative depilatory versus razor preparation. Am J Surg 1971;121:251-254.

95. Alexander JW, Fischer JE, Boyajian M, Palmquist J, Morris MJ. The influence of hair-removal methods on wound infections. Arch Surg 1983;118:347-352.

96. Singer AJ, Hollander JE, Subramanian S, Malhotra AK, Villez P. Pressure dynamics of various irrigation techniques commonly used in the emergency department. Ann Emerg Med 1994;24:36-40.

97. Stevenson TR, Thacker JG, Rodeheaver GT, Bacchetta C, Edgerton MT, Edlich RF. Cleansing the traumatic wound by high pressure syringe irrigation. JACEP 1976;5:17-21.

98. Longmire AW, Broom LA. Wound infection following high-pressure syringe and needle irrigation. Am J Emerg Med 1987;5:179-181.

99. Morse JW, Babson T, Camasso C, Bush AC, Blythe PA. Wound infection rate and irrigation pressure of two potential new wound irrigation devices: the port and the cap. Am J Emerg Med 1998;16:37-42.

100. Dire DJ, Welsh AP. A comparison of wound irrigation solutions used in the emergency department. Ann Emerg Med 1990;19:704-708.

101. Hollander JE, Richman PB, Werblud M, Miller T, Huggler J, Singer AJ. Irrigation in facial and scalp lacerations: does it alter outcome? Ann Emerg Med 1998;31:73-77.

102. Wheeler CB, Rodeheaver GT, Thacker JG, Edgerton MT, Edlich RF. Side-effects of high pressure irrigation. Surg Gynecol Obstet 1976;143:775-778.

103. Haury B, Rodeheaver G, Vensko J, Edgerton MT, Edlich RF. Debridement: an essential component of traumatic wound care. Am J Surg 1978;135:238-242.

104. Milewski PJ, Thomson H. Is a fat stitch necessary? Br J Surg 1980;67:393-394.

105. deHoll D, Rodeheaver G, Edgerton MT, Edlich RF. Potentiation of infection by suture closure of dead space. Am J Surg 1974;137:716-720.

106. Magee C, Rodeheaver GT, Golden GT, Fox J, Edgerton MT, Edlich RF. Potentiation of wound infection by surgical drains. Am J Surg 1976;131:547-549.

107. Bennett RG. Selection of wound closure materials. J Am Acad Dermatol 1988;18:619-637.

108. Grisham JE, Zukin D. Suture selection for the pediatrician. Pediatr Emerg Care 1990;6:301-304.

109. Edlich RF, Panek PH, Rodeheaver GT, Turnbull VG, Kurtz LK, Edgerton MT. Physical and chemical configuration of sutures in the development of surgical infection. Ann Surg 1973;177:679-688.

110. Sharp WV, Belden TA, King PH, Teague PC. Suture resistance to infection. Surgery 1982;91:61-63.

111. Guyuron B, Vaughan C. A comparison of absorbable and nonabsorbable suture materials for skin repair. Plast Reconstr Surg 1992;89:234-236.

112. Scaccia RJ, Hoffman JA, Stepnick DW. Upper eyelid blepharoplasty: a technical comparative analysis. Arch Otolaryngol Head Neck Surg 1994;120:827-830.

113. Lubitz D, Coyne C, Windle B. Use of fast absorbable sutures for the repair of pediatric facial lacerations (abstract). Arch Pediatr Adolesc Med 1944;148 (Suppl):42-43.

114. Start NJ, Armstrong AM, Robson WJ. The use of chromic catgut in the primary closure of scalp wounds in children. Arch Emerg Med 1989;6:216-219.

115. George TK, Simpson DC. Skin wound closure with staples in the accident and emergency department. J R Coll Surg Edinb 1985;30:54-56.

116. Ritchie AJ, Rocke LG. Staples versus sutures in the closure of scalp wounds: a prospective, double-blind, randomized trial. Injury 1989;20:217-218.

117. Kanegaye J, Vance C, Chan L, Schonfeld N. Comparison of skin stapling devices and standard sutures for pediatric scalp lacerations: a randomized study of cost and time benefits. J Pediatr 1997;130:808-813.

118. McDowell AJ. Extravagant treatment of garden variety lacerations. Plast Reconstr Surg 1979;63:111-112.

119. Bruns TB, Simon HK, McLario DJ, Sullivan KM, Wood RJ, Anand KJS. Laceration repair using a tissue adhesive in a children's emergency department. Pediatrics 1996;98:673-675.

120. Quinn JV, Drzewiecki A, Li MM, Stiell IG, Sutcliffe T, Elmslie TJ, et al. A randomized, controlled trial comparing a tissue adhesive with suturing in the repair of pediatric facial lacerations. Ann Emerg Med 1993;22:1130-1135.

121. Simon HK, McLario DJ, Bruns TB, Zempsky WT, Wood RJ, Sullivan KM. Long-term appearance of lacerations repaired using a tissue adhesive. Pediatrics 1997;99:193-195.

122. Bresnahan KA, Howell JM, Wizorek J. Comparison of tensile strength of cyanoacrylate tissue adhesive closure of lacerations versus suture closure. Ann Emerg Med 1995;26:575-578.

123. Noordzij JP, Foresman PA, Rodeheaver GT, Quinn JV, Edlich RF. Tissue adhesive wound repair revisited. J Emerg Med 1994;12:645-649.

124. Myers BM, Cherry G. Functional and angiographic vasculature in healing wounds. Am Surg 1970;36:750-756.

125. Thirlby RC, Blair J, Thal ER. The value of prophylactic antibiotics for simple lacerations. Surg Gynecol Obstet 1983;156:212-216.

126. Mehta PH, Dunn KA, Bradfield JF, Austin PE. Contaminated wounds: infection rates with subcutaneous sutures. Ann Emerg Med 1996;27:43-48.

127. Jones JS, Gartner M, Drew G, Pack S. The shorthand vertical mattress stitch: Evaluation of a new suture technique. Am J Emerg Med 1993;11:483-485.

128. Winn HR, Jane JA, Rodeheaver H, Edgerton MT, Edlich RF. Influence of subcuticular sutures on scar formation. Am J Surg 1977;133:257-259.

129. Foster GE, Hardy EG, Hardcastle JD. Subcuticular suturing after appendicectomy. Lancet 1977;1:1128-1129.

130. Edlich RF, Rodeheaver GT, Morgan RF, Berman DE, Thacker JG. Principles of emergency wound management. Ann Emerg Med 1988;17:1284-1302.

131. Robson MC, Duke WF, Krizek TJ. Rapid bacterial screening in the treatment of civilian wounds. J Surg Res 1973;114:426-430.

132. Edlich RF, Rogers W, Kasper G, Kaufman D, Tsung MS, Wangensteen OH. Studies in the management of the contaminated wound: I. Optimal time for closure of contaminated open wounds II. Comparison of resistance to infection of open and closed wounds during healing. Am J Surg 1969;117:323-329.

133. Davies MJ. Scalp wounds. An alternative to suture. Injury 1988;19:375-376.

134. Hubbard KA, Klein BL, Hernandez M, Forrester D, Chamberlain JM. Mandibular fractures in children with chin lacerations. Pediatr Emerg Care 1995;11:83-85.

135. Voit GA, Irvine G, Beals RK. Saline load test for penetration of periarticular lacerations. J Bone Joint Surg [Br] 1996;78-B:732-733.

136. Inglefield CJ, D'Arcangelo M, Kolhe PS. Injuries to the nail bed in childhood. J Hand Surg [Br] 1995;20B:258-261.

137. Zook EG. Nail bed injuries. Hand Clin 1985;1:701-716.

138. Simon RR, Wolgin M. Subungual hematoma: association with occult laceration requiring repair. Am J Emerg Med 1987;5:302-304.

139. Wee GC, Shieber W. Painless evacuation of the subungual hematoma. Surg Gynecol Obstet 1970;131:531.

140. Seaberg DC, Angelos WJ, Paris PM. Treatment of subungual hematomas with nail trephination: a prospective study. Am J Emerg Med 1991;9:209-210.

141. Illingworth CM. Trapped fingers and amputated finger tips in children. J Pediatr Surg 1974;9:853-858.

142. Douglas BS. Conservative management of guillotine amputation of the finger in children. Aust Paediatr J 1972;8:86-89.

143. Sloan JP, Dove AF, Maheson M, Cope AN, Welsh KR. Antibiotics in open fractures of the distal phalanx? J Hand Surg [Br] 1987;12:123-124.

144. Suprock MD, Hood JM, Lubahn JD. Role of antibiotics in open fractures of the finger. J Hand Surg [Am] 1990;15:761-764.

145. Callaham M. Prophylactic antibiotics in common dog bite wounds: a controlled study. Ann Emerg Med 1980;9:410-414.

146. Ordog GJ. The bacteriology of dog bite wounds on initial presentation. Ann Emerg Med 1986;15:1324-1329.

147. Dire DJ. Cat bite wounds: risk factors for infection. Ann Emerg Med 1991;20:973-979.

148. Schweich P, Fleisher G. Human bites in children. Pediatr Emerg Care 1985;1:51-53.

149. Cummings P. Antibiotics to prevent infection in patients with dog bite wounds: a meta-analysis of randomized trials. Ann Emerg Med 1994;23:535-540.

150. Callaham M. Prophylactic antibiotics in dog bite wounds: nipping at the heels of progress. Ann Emerg Med 1994;23:577-579.

151. Callaham M. Controversies in antibiotic choices for bite wounds. Ann Emerg Med 1988;17:1321-1330.

152. Dire DJ. Emergency management of dog and cat bite wounds. Emerg Med Clin North Am 1992;10:719-736.

153. Edlich RF, Madden JE, Prusak M, Panek P, Thul J, Wangensteen OH. Studies in the management of the contaminated wound: VI. The therapeutic value of gentle scrubbing in prolonging the limited period of effectiveness of antibiotics in contaminated wounds. Am J Surg 1971;121:668-672.

154. American Academy of Pediatrics. Bite wounds. In: Peter G, ed. 1997 Red Book: Report of the Committee on Infectious Diseases, 24th ed. Elk Grove Village, IL: American Academy of Pediatrics; 1997. p. 122-126.

155. Bailie WE, Stowe EC, Schmitt AM. Aerobic bacterial flora of oral and nasal fluids of canines with reference to bacteria associated with bites. J Clinl Microbiol 1978;7:223-231.

156. Brook I. Microbiology of human and animal bite wounds in children. Pediatr Infect Dis J 1987;6:29-32.

157. Brakenbury PH, Muwanga C. A comparative double blind study of amoxycillin/clavulanate *vs* placebo in the prevention of infection after animal bites. Arch Emerg Med 1989;6:251-256.

158. Goldstein EJC, Reinhardt JF, Murray PM, Finegold SM. Outpatient therapy of bite wounds: demographic data, bacteriology, and a prospective, randomized trial of amoxicillin/clavulanic acid versus penicillin ± dicloxacillin. Int J Dermatol 1987;26:123-126.

159. American Academy of Pediatrics. Rabies. In: Peter G, ed. 1997 Red Book: Report of the Committee on Infectious Diseases, 24th ed. Elk Grove Village, IL: American Academy of Pediatrics; 1997. p. 435-442.

160. Lobe TE, Anderson GF, King DR, Boles ET. An improved method of wound management for pediatric patients. J Pediatr Surg 1980;15:886-889.

161. Cockington RA. Ambulatory management of burns in children. Burns 1989;15:271-273.

162. Winton GB, Salasche SJ. Wound dressings for dermatologic surgery. Journal of the American Academy of Dermatology 1985;13:1026-1044.

163. Dire DJ, Coppola M, Dwyer DA, Lorette JJ, Karr JL. Prospective evaluation of topical antibiotics for preventing infections in uncomplicated soft-tissue wounds repaired in the ED. Acad Emerg Med 1995;2:4-10.

164. Phillips TJ, Kapoor V, Provan A, Ellerin T. A randomized prospective study of a hydroactive dressing vs conventional treatment after shave biopsy excision. Arch Dermatol 1993;129:859-860.

165. Ship AG, Weiss PR. Pigmentation after dermabrasion: an avoidable complication. Plast Reconstr Surg 1985;75:528-532.

166. Fulton JE. The stimulation of postdermabrasion wound healing with stabilized aloe vera gel-polyethylene oxide dressing. J Dermatol Surg Oncol 1990;16:460-467.

167. Lee M. An investigation into the value of D, L-alpha-tocopheryl acetate (vitamin E) in the treatment of gravitational ulcers. Br J Dermatol 1953;65:131-138.

168. Jenkins M, Alexander W, MacMillan BG, Waymakc JP, Kopcha R. Failure of topical steroids and vitamin E to reduce postoperative scar formation following reconstructive surgery. J Burn Care Rehabil 1986;7:309-312.

169. American Academy of Pediatrics. Tetanus. In: Peter G, ed. 1997 Red Book: Report of the Committee on Infectious Diseases, 24th ed. Elk Grove Village, IL: American Academy of Pediatrics; 1997. p. 518-523.

170. Rosenberg NM, Debaker K. Incidence of infection in pediatric patients with laceration. Pediatr Emerg Care 1987;3:239-241.

171. Hollander JE, Singer AJ, Valentine S, Henry MC. Wound registry: development and validation. Ann Emerg Med 1995;25:675-685.

172. Classen DC, Evans RS, Pestotnik SL, Horn SD, Menlove RL, Burke JP. The timing of prophylactic administration of antibiotics and the risk of surgical-wound infection. N Engl J Med 1992;326:281-286.

173. Grossman JAI, Adams JP, Kunec J. Prophylactic atibiotics in simple hand lacerations. JAMA 1981;245:1005-1056.

174. Steele MT, Sainsbury CR, Robinson WA, Salomone JA, Elenbaas RM. Prophylactic penicillin for intraoral wounds. Ann Emerg Med 1989;18:847-852.

175. Edlich RF, Smith QT, Edgerton MT. Resistance of the surgical wound to antimicrobial prophylaxis and its mechanisms of development. Am J Surg 1973;126:583-591.

176. Goldberg HM, Rosenthal SAE, Nemetz JC. Effect of washing closed head and neck wounds on wound healing and infection. Am J Surg 1981;141:358-359.

177. Seaman M, Lammers R. Inability of patients to self-diagnose wound infections. J Emerg Med 1991;9:215-219.

178. Hawk W, Crockett RK, Ochsenschlager DW, Klein BL. Conscious sedation of the pediatric patient for suturing: a survey. Pediatr Emerg Care 1990;6:84-88.

179. Bauchner H, Vinci R, Waring C. Pediatric procedures: Do parents want to watch? Pediatrics 1989;84:907-909.

180. Sacchetti A, Lichenstein R, Carraccio CA, Harris RH. Family member presence during pediatric emergency department procedures. Pediatr Emerg Care 1996;12:268-271.

181. American Academy of Pediatrics, Committee on Drugs. Guidelines for monitoring and management of pediatric patients during and after sedation for diagnostic and therapeutic procedures. Pediatrics 1992;89:1110-1115.

182. Sacchetti A, Schafermeyer R, Gerardi M, Graneto J, Fuerst RS, Cantor R, et al. Pediatric analgesia and sedation. Ann Emerg Med 1994;23:237-250.

183. Ingebo KR, Rayborn NJ, Hecht RM, Shelton MT, Silber GH, Shub MD. Sedation in children: adequacy of two-hour fasting. J Pediatr 1997;131:155-158.

184. Schreiner MS, Nicolson SC, Martin T, Whitney L. Should children drink before discharge from day surgery? Anesthesiology 1992;76:528-533.

185. Coté CJ. Sedation for the pediatric patient. Pediatr Clin North Am 1994;41:31-58.

186. Bailey PL, Pace NL, Ashburn MA, Moll JWB, East KA, Stanley TH. Frequent hypoxemia and apnea after sedation with midazolam and fentanyl. Anesthesiology 1990;73:826-830.

187. Hennes HM, Wagner V, Bonadio WA, Glaeser PW, Losek JD, Wash-Kelly CM, et al. The effect of oral midazolam on anxiety of preschool children during laceration repair. Ann Emerg Med 1990;19:1006-1009.

188. Connors K, Terndrup TE. Nasal versus oral midazolam for sedation of anxious children undergoing laceration repair. Ann Emerg Med 1994;24:1074-1079.

189. Theroux MC, West DW, Corddry DH, Hyde PM, Bachrach SJ, Cronan KM, et al. Efficacy of intranasal midazolam in facilitating suturing of lacerations in preschool children in the emergency department. Pediatrics 1993;91:624-627.

190. Shane SA, Fuchs SM, Khine H. Efficacy of rectal midazolam for the sedation of preschool children undergoing laceration repair. Ann Emerg Med 1994;24:1065-1073.

191. Karl HW, Rosenberger JL, Larach MG, Ruffle JM. Transmucosal administration of midazolam for premedication of pediatric patients. Anesthesiology 1993;78:885-891.

192. Bilmire DA, Neale HW, Gregory RO. Use of IV fentanyl in the outpatient treatment of pediatric facial trauma. J Trauma 1985;25:1079-1080.

193. Schutzman SA, Burg J, Leibelt E, Strafford M, Schechter N, Wisk M, et al. Oral transmucosal fentanyl citrate for premedication of children undergoing laceration repair. Ann Emerg Med 1994;24:1059-1064.

194. Yaster M, Nichols DG, Deshpande JK, Wetzel RC. Midazolam-fentanyl intravenous sedation in children: case report of respiratory arrest. Pediatrics 1990;86:463-466.

195. Burton JH, Auble TE, Fuchs SM. Effectiveness of 50 % nitrous oxide/50 % oxygen during laceration repair in children. Acad Emerg Med 1998;5:112-117.

196. Green SM, Nakamura R, Johnson NE. Ketamine sedation for pediatric procedures: part 1, a prospective series. Ann Emerg Med 1990;19:1024-1032.

197. Green SM, Johnson NE. Ketamine sedation for pediatric procedures: part 2, review and implications. Ann Emerg Med 1990;19:1033-1046.

198. American Academy of Pediatrics, Committee on Drugs. Reappraisal of lytic cocktail/demerol, phenergan, and thorazine (DPT) for the sedation of children. Pediatrics 1995;95:598-602.

Figure 1. Layers of a typical deep scalp laceration. Subcutaneous tissue, fascia of occipitalis muscle, and bone exposed by a defect in the periosteum are revealed.

Figure 2. Instrument tie technique, right-handed clinician. A. Knot initiated by wrapping long end of suture around needle holder. Depicted is the “surgeon’s” knot with 2 wraps; a standard square knot is initiated with a single wrap. B. First throw cinched down from left to right. C. Second portion of the knot initiated by wrapping suture around needle holder in opposite direction of previous throw. D. Second throw completed and cinched down from right to left. One to four additional throws in alternating directions will complete the knot, depending on suture material.

Figure 3. Placement of the dermal suture. A. The needle passes from deep to superficial within the dermis. B. The loop is completed with a bite from superficial to deep within the dermis on the opposite side of the wound, never penetrating the surface of the skin. Both ends of the suture are pulled toward the clinician to keep them on the same side of the loop before tying the buried knot.

Figure 4. Vertical mattress suture. A. Standard method (“far-far-near-near”). This suture begins much as the standard interrupted suture. The needle is reversed, and small inner bites are taken. B. Appearance of the completed suture with excellent wound edge eversion. C. Shorthand method (“near-near-far-far”). Small backhand bites are taken first. Traction on the initial suture loop by the non-dominant hand allows the outer loop to be accomplished in a single bite.

Figure 5. Placement of the half-buried horizontal mattress suture. A. Y-shaped stellate laceration. B. T-shaped stellate laceration.

Figure 6. Management of the dog-ear. A. Dog-ear created by careless approximation of landmarks, leaving an unsightly fold of excessive tissue in the lower right margin of the wound. The running suture technique prevents revision without extensive re-suturing. B. Skin fold has relaxed after the wound is extended obliquely in direction of excess tissue. C. Excess skin excised to create 2 matching edges. D. Newly extended wound closed by standard technique.