

# Laceration Management

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In 1996, almost 11 million lacerations were treated in emergency departments throughout the United States. Although most lacerations heal without sequelae regardless of management, mismanagement may result in wound infections, prolonged convalescence, unsightly and dysfunctional scars, and, rarely, mortality. The goals of wound management are simple: avoid infection and achieve a functional and aesthetically pleasing scar. Recent US Food and Drug Administration approval of tissue adhesives has significantly expanded clinicians' wound closure options and improved patient care. We review the general principles of wound care and expand on the use of tissue adhesives for laceration repair.

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## INTRODUCTION

Lacerations are one of the most commonly encountered problems in the emergency department. In 1996, almost 11 million wounds were treated in EDs throughout the United States.<sup>1</sup> At an average charge of \$200 per patient, this translates to more than \$2 billion annually. The principles of wound care have remained remarkably the same over the years. Although most lacerations heal without sequelae regardless of management, mismanagement may result in wound infections, prolonged convalescence, unsightly and dysfunctional scars, and, very rarely, mortality. The goals of wound management are simple: avoid infection and achieve a functional and aesthetically pleasing scar.<sup>2</sup> These goals may be achieved by reducing tissue contamination, debriding devitalized tissue, restoring perfusion in poorly perfused wounds, and establishing a well-approximated skin closure.

Most lacerations require primary closure. Primary closure results in more rapid healing and reduced patient discomfort than does secondary closure. The most commonly used method for closing lacerations remains sutur-

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ing.<sup>3</sup> The recent US Food and Drug Administration (FDA) approval of tissue adhesives has significantly expanded clinicians' wound closure options and improved patient care. In this article we review the general principles of wound care and expand on the use of tissue adhesives for laceration repair.

Most wound care practices are empirical or based on animal wound models. Few are based on well-designed clinical trials. Most studies of laceration management have focused on the wound infection rate as the primary outcome, despite the fact that wound infections are relatively uncommon (less than 5% of lacerations).<sup>3-5</sup> Although all traumatic lacerations should be considered contaminated, most have low bacterial counts (fewer than 100 organisms per gram of tissue), well below the infectious inoculum of  $10^5$  or more organisms per gram.<sup>6</sup> Furthermore, most infected lacerations heal without complications other than the occasional unsightly scar. Investigators have come to appreciate that patients are most concerned with the cosmetic appearance of their healed lacerations,<sup>7</sup> and the focus of wound research has shifted toward measuring wound cosmesis as the primary outcome. Both continuous and categorical scales have been developed and validated for measuring cosmetic outcome after laceration repair, and these instruments should be used in any clinical trials evaluating laceration repair.<sup>3,8,9</sup>

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## HISTORY OF WOUNDS

Human beings have managed wounds from the beginning of civilization. The first evidence of wounds can be found in our ancestor, *Australopithecus africanus*, who lived more than 5 million years ago.<sup>10</sup> The first written records of wounds date back to 2500 BC.<sup>11</sup> Initial treatments for wounds consisted of herbal balms or draughts with application of leaves or grasses as bandages. Ointments were made from a wide variety of animal, vegetable, and mineral substances. Wounds were mostly left open, although wound closure using the jaws of ants was used by some cultures.<sup>12</sup> The world's oldest suture was placed by an embalmer on the abdomen of a mummy in approximately 1100 BC.<sup>10</sup> During early civilization, the care of wounds was dominated by magic and rituals. Celsus first described primary and secondary wound closure more than 2,000 years ago.

During the Middle Ages, pus was believed to be necessary for healing; as a result, various agents were used to promote suppuration. Advances in the fields of anesthesiology and surgery during the past 2 centuries have led to

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the development of many of the practices that are prevalent today. These are based on thorough debridement and cleansing of wounds and use of aseptic wound closure techniques. Only recently has wound care been systematically investigated both in the laboratory and in clinical arenas.

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## EPIDEMIOLOGY OF LACERATIONS AND WOUND CHARACTERISTICS

Lacerations occur predominantly in young adults.<sup>3</sup> Of almost 5,000 patients with lacerations treated at 1 institution over the last 3 years, the median age was 20 years, with a range of 0 to 97 years (personal observation, JH, AS, 1998). Approximately one third of lacerations occurred in adults between the ages of 19 and 35 years. The majority of patients with lacerations are men. Most wounds are located either on the head or neck (50%) or on an upper extremity (35%), usually involving the fingers or hands. The most common mechanism of injury is application of a blunt force, such as bumping the head against a coffee table. Such contact crushes the skin against an underlying bone, causing it to split. Other agents of injury include sharp instruments, glass, and wooden objects.<sup>3</sup> Although mammalian bites continue to receive much attention, they are a relatively rare cause of lacerations.

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## EVALUATION OF THE PATIENT WITH A LACERATION

It is important to identify conditions that place the patient at risk for infection or delayed healing after wound closure. A prospective study by Cruise and Foord,<sup>13</sup> in which more than 23,000 surgical incisions were observed, identified diabetes mellitus, obesity, malnutrition, chronic renal failure, advanced age, and use of steroids as risk factors for increased wound infection rates. All of these risk factors, together with the use of chemotherapeutic agents and other immunosuppressive agents, may delay wound healing by affecting inflammation and the synthesis of new wound matrix and collagen.<sup>14</sup>

Because anesthetic agents and antibiotics may be required for many patients, a detailed history of any allergies to these agents is essential. With the increased incidence of severe reactions to latex products, it is also vital to review any previous allergies to latex. Tetanus immunization status should be verified. The need for further vaccination should be determined according to the recommendations of the US Centers for Disease Control and Prevention (Table 1).

## EVALUATION OF THE LACERATION

A history of the mechanism of injury is essential to help identify the presence of any potential wound contaminants and foreign bodies that can result in chronic infection and delayed healing. Failure to diagnose foreign bodies is the fifth leading cause of litigation against emergency physicians.<sup>15</sup> Other common wound-related causes of litigation include the development of wound infections and missed injuries of tendons and nerves. The types of forces applied at the time of injury help predict the likelihood of infection. Crush injuries, which tend to cause greater devitalization of tissue, are more susceptible to infection than are wounds resulting from the more common shearing forces.<sup>16</sup>

Adequate wound examination should always be conducted under optimal lighting conditions with minimal bleeding. cursory examination under poor lighting conditions or when the depths of the wound are obscured by blood ultimately result in underdetection of embedded foreign bodies and damage to important structures such as tendons, nerves, and arteries. One way to minimize the possibility of missing an injury to a vital structure is to start the wound examination with a neurovascular assessment of pulses, motor function, and sensation distal to the laceration.

Despite the fact that few studies have clearly demonstrated the benefit of the use of sterile gloves for repair of routine lacerations in the ED,<sup>17,18</sup> this practice is still recommended. In a study comparing 239 patients whose lacerations were repaired by a gloved operator wearing a cap and mask with 203 patients whose wounds were repaired by a gloved operator not using a cap or masks, Ruthman et al<sup>19</sup> found comparable wound infection rates. In a similarly provocative study, Whorl<sup>20</sup> compared wound healing and infection rates in patients randomly

assigned to laceration repair either with full sterile technique or with a surgically clean technique in which the laceration was repaired after irrigation with tap water and without the use of a mask or sterile gloves. Fewer infections were noted in the group whose wounds were repaired by the surgically clean technique. Although this study had many methodologic limitations (lack of blinding, lack of control for patient and wound characteristics), it questions the classic dictum that requires sterile technique during wound repair. The use of some type of gloves is necessary to comply with universal precautions. Although they are more costly, powder-free gloves may further reduce the risk of any foreign body reactions or infections that may theoretically result from the introduction of talc particles into the wound.<sup>21</sup>

## ANESTHESIA OF THE LACERATION

For adequate evaluation and management, many lacerations require anesthesia. There are 2 major classes of local anesthetics: esters and amides (Table 2). Although many patients report having had an "allergic reaction" to a local anesthetic in the past, careful review usually reveals either a vasovagal response associated with painful injection or evidence of minor toxicity from the anesthetic agent. Rarely, patients may report a true allergy to 1 of the local anesthetics. Because there is little cross-reactivity between agents of the 2 classes, use of an agent from the other class may be appropriate. Many patients with supposed allergies to lidocaine are actually allergic to methylparaben, the preservative used in multidose vials. This preservative is similar in molecular structure to 1 of the degradation products of the ester anesthetics. As a result, the use of an amide in place of an ester may be problematic. One alternative is to use single-dose lidocaine (cardiac lidocaine), which does not contain a preservative.

Table 1.

Recommendations for tetanus prophylaxis.

History of Tetanus Immunization	Clean Minor Wounds		All Other Wounds*	
	Td	TIG	Td	TIG
Uncertain or <3 doses	Yes	No	Yes	Yes
≥3 doses				
Last dose within 5 y	No	No	No	No
Last dose 5–10 y	No	No	Yes	No
Last dose >10 y	Yes	No	Yes	No

Td, Tetanus-diphtheria toxoid; TIG, tetanus immune globulin.

\*For example, contaminated wounds, puncture wounds, avulsions, burns, crush injuries.

Another option is to use an anesthetic agent unrelated to the amides, such as diphenhydramine or benzyl alcohol.

Although various concentrations of diphenhydramine have been shown to be effective, their administration is more painful than administration of lidocaine.<sup>22,23</sup> Attempts to reduce the pain of injection of diphenhydramine by buffering have not been successful.<sup>24</sup> If diphenhydramine is used, it is important to dilute the solution to 1% to avoid the risk of tissue necrosis. Benzyl alcohol (commonly found as a preservative in vials of normal saline solution) has been shown to be as effective as lidocaine yet significantly less painful to inject than diphenhydramine.<sup>25</sup> When 0.9% benzyl alcohol with epinephrine is used, the duration of action is longer than for diphenhydramine.<sup>26</sup>

Although many local anesthetics are available, the 2 most commonly used are lidocaine and mepivacaine. The onset of mepivacaine is delayed, but its longer duration of action offers a significant advantage over lidocaine, particularly when prolonged pain is anticipated (Table 2).

Local anesthesia may be achieved by several routes (Table 3). Most commonly, anesthetics are administered by local infiltration. Although this method is the most reliable, local infiltration is painful and subjects the practitioner to the risk of a needle stick. To reduce the pain of injection, many methods have been investigated. Buffering of the local anesthetic with sodium bicarbonate at a ratio of 1:10 increases the ratio of uncharged to charged molecules, resulting in more rapid and less painful onset of anesthesia.<sup>27</sup> The solution has been shown to have a shelf life of at least 1 week.<sup>28</sup> The change in the pH of the anesthetic solution does not increase wound infection rates.<sup>29</sup> Similarly, most studies have found that warming of the anesthetic solution to body temperature reduces the pain associated with infil-

tration.<sup>30</sup> In a study of 45 patients, Brogan et al<sup>31</sup> found that warming was as effective as buffering of local anesthetics. A study by Scarfone et al<sup>32</sup> in 42 adult volunteers found that slowing the rate of injection of lidocaine was even more effective than buffering for reducing the pain of infiltration. However, this effect has been disputed by others.<sup>33</sup> The pain of infiltration also may be reduced by injecting the local anesthetic through the wounded edges of the laceration instead of through the intact surrounding skin.<sup>34</sup> Use of smaller needles and subcutaneous rather than intradermal injection have also been suggested to result in less pain.<sup>35</sup> Another approach to reducing the pain of local infiltration is to use a topical anesthetic before injection. Although topical lidocaine 2% does not appear to have any effect,<sup>36</sup> Bartfield et al<sup>37</sup> showed that topical tetracaine 1% attenuates the pain of infiltration of buffered lidocaine.

Alternative methods of administration of local anesthesia include topical and regional application. Topical application of anesthetics obviates the use of needles, eliminating the risk of inadvertent needle sticks and allowing painless application. A combination of tetracaine, adrenaline, and cocaine (TAC) has been shown to be an effective topical anesthetic before repair of lacerations, particularly in children and on the face and scalp.<sup>38-40</sup> However, improper use of TAC has been associated with serious adverse events (eg, seizures, death),<sup>41,42</sup> leading to the development of alternative topical combinations. Various combinations of lidocaine (1% to 4%), adrenaline (1:1,000 to 1:2,000), and tetracaine (0.5% to 2%) have compared favorably with topical application of TAC, without the associated risks and administrative complications of cocaine.<sup>43-45</sup> Zempsky and Karasic<sup>46</sup> compared EMLA cream (eutectic mixture of local anesthetics) with TAC before repair of extremity lacerations. Supplemental infiltration of lidocaine was

**Table 2**

*Properties of commonly used local anesthetics.*

Agent	Trade Name	Local Class Anesthetic	Concentration (%)	Maximal Safe Dose (mg/kg)	Onset (min)	Duration (h)
Procaine	Novocaine	Ester	0.5-1.0	7	2-5	0.25-0.75
Procaine with epinephrine				9		0.5-1.5
Lidocaine	Xylocaine	Amide	0.5-2.0	4.5	2-5	1-2
Lidocaine with epinephrine				7		2-4
Bupivacaine	Marcaine	Amide	0.125-0.25	2	2-5	4-8
Bupivacaine with epinephrine				3		8-16

required for only 15% of patients receiving EMLA, compared with 55% of patients in the TAC group. However, the onset of anesthesia was delayed in the EMLA group (55 versus 29 minutes), limiting its use in the ED. Novel methods for enhancing topical absorption of local anesthetics, such as iontophoresis<sup>47</sup> and sonophoresis,<sup>48</sup> have been proposed and are being explored. A study by Singer et al<sup>49</sup> suggested that removal of the stratum corneum by peeling the skin with Scotch tape may also be an effective method to accelerate the onset of anesthesia from topical EMLA cream.

Local anesthetics may also be administered regionally by injecting them around a regional sensory nerve. Regional anesthesia has the benefit of offering anesthesia of relatively large areas of skin with minimal doses of anesthetics, reducing the risks of toxicity. This method is particularly helpful with multiple lacerations or when large areas of skin must be scrubbed or debrided (eg, road rashes, multiple imbedded glass fragments). Methods to reduce the pain of regional anesthesia include buffering and intraoral rather than transcutaneous administration where appropriate (eg, for mental and infraorbital nerve blocks).<sup>50,51</sup> Although intraoral infiltration is less painful for patients, it increases the risk of inadvertent needle sticks.

## WOUND PREPARATION

Removal of the hair surrounding a laceration helps facilitate meticulous wound closure. Because many bacteria normally reside in hair follicles, shaving of the hair before repair may increase wound infection rates.<sup>52</sup> Reduced damage to hair follicles may be achieved with the use of hair clippers instead of a razor. Most practitioners avoid removal of the eyebrow hair, because its removal may result in abnormal regrowth and its presence serves as a guide for exact approximation of wound edges during laceration repair.

Direct scrubbing of the wound with a sterile surgical brush helps remove both bacteria and particulate matter that potentiate the risk of wound infection. However,

**Table 3.**

*Methods to reduce pain of local infiltration for lidocaine.*

Small-bore needles (27- to 30-gauge)
Buffered solutions
Warmed solutions
Slow rates of injection
Injection through wound edges
Subcutaneous rather than intradermal injection
Pretreatment with topical anesthetics

scrubbing also contributes to tissue damage and reduces the ability of the wound to resist infection. To achieve the beneficial effects of scrubbing while reducing its deleterious effects, a high-porosity sponge and a tissue surfactant such as Pluronic F-68 or poloxamer 188 (Shur-Clens) may be used.<sup>53</sup> Because the use of high-porosity sponges and surfactants adds to the cost, their use is probably justified only for highly contaminated wounds.

Nonviable tissue may impair the ability of the laceration to resist infection.<sup>54</sup> Therefore, surgical debridement of any crushed or devitalized tissue is one of the most fundamental aspects of wound preparation.

## IRRIGATION OF THE LACERATION

There is considerable debate regarding the exact methods of irrigation and the nature of the irrigant solutions. The efficacy of wound irrigation can be correlated with the pressure at which the irrigant is delivered to the wound.<sup>55</sup> In an experimental animal contaminated wound model, Stevenson et al<sup>56</sup> clearly demonstrated the effectiveness of high-pressure irrigation in reducing both bacterial wound counts and wound infection rates, compared with low-pressure irrigation. Despite earlier debate, continuous irrigation is probably just as effective as pulsatile irrigation.<sup>55</sup> However, sustained high-pressure irrigation may also be associated with increased tissue damage, and at very high pressures infection rates actually increase.<sup>57</sup> Therefore, the optimal irrigation pressure lies somewhere in between. Despite the lack of clinical studies, most authorities recommend irrigation impact pressures in the range of 5 to 8 psi.<sup>58</sup> In each case, the benefits of high-pressure irrigation should be weighed against the potential risks. For noncontaminated wounds in highly vascularized areas containing loose areolar tissue, such as the eyelid, high pressures should be avoided. Conversely, high-pressure irrigation is clearly indicated for contaminated wounds of the lower extremity. Although there have been attempts to estimate the tissue impact pressure, no direct pressures have been measured. Wound impact pressures in the range of 5 to 8 psi can easily be obtained with the use of a 30- to 60-mL syringe and a 19-gauge needle<sup>56</sup> or Zerowet splash shield (Zerowet, Inc, Palos Verdes Peninsula, CA). However, when such devices were tested, higher irrigation pressures were measured within the irrigating system, emphasizing the need for careful selection of irrigation techniques.<sup>59</sup>

An observational study comparing wound infection rates and cosmetic appearance at the time of suture removal demonstrated comparable results when facial

wounds were repaired with and without irrigation.<sup>60</sup> Although these findings need to be validated by a well-designed clinical trial, they suggest that irrigation may not be required for all low-risk wounds, particularly in an area with a good vascular supply, such as the face.

The choice of an appropriate wound irrigant is more straightforward. Although many irrigant solutions have been suggested and tested, normal saline solution remains the most cost-effective and readily available choice.<sup>61</sup> An animal study in a contaminated wound model suggested that irrigation of wounds with tap water under pressure may be a reasonable alternative to saline irrigation.<sup>62</sup> However, these findings also need to be validated in the clinical setting before they are widely adopted. Because of their tissue toxicity, detergents, hydrogen peroxide, and concentrated forms of povidone-iodine should not be used to irrigate wounds.<sup>63,64</sup>

The volume of irrigation should be determined according to patient and wound characteristics such as location and cause of the wound. Use of a device to reduce the amount of splatter during irrigation is encouraged to minimize the risk of exposure of the practitioner to potentially infectious materials.<sup>65</sup>

## WOUND CLOSURE

Most wounds should be closed primarily to reduce patient discomfort and speed healing. Although there is a direct relation between the time interval from injury to laceration closure and the risk of subsequent infection, the length of this "golden period" is highly variable.<sup>66-68</sup> In one study of 300 hand and forearm lacerations, Morgan et al found that lacerations closed within 4 hours had a lower infection rate than lacerations closed more than 4 hours after injury (7% versus 21%, respectively).<sup>66</sup> On the other hand, Baker and Lanuti<sup>67</sup> did not find a difference in infection rate for lacerations closed less than or more than 6 hours from the time of injury in 2,834 pediatric patients. The most widely quoted study comes from Jamaica, where healing (defined as epithelization without infection) was the main outcome.<sup>68</sup> In this study of 204 lacerations, facial lacerations healed well regardless of the time to closure. In contrast, trunk and extremity lacerations had lower rates of healing if they were closed more than 19 hours after the time of injury (63% to 75%) than if they were closed earlier (75% to 91%); however, the subgroups were small, ranging from 8 to 44 patients.<sup>68</sup>

Based on these studies, it seems most prudent to consider each individual laceration separately, taking the time from injury until presentation into account in addition to lac-

eration location, contamination, risk of infection, and importance of cosmetic appearance before deciding whether to perform primary wound closure. For example, a 20-hour-old laceration on the face of a healthy 4-year-old child may be closed primarily, whereas a deep laceration from a puncture in the foot of a diabetic patient carries a very high risk of infection and should not be closed primarily. The period during which wound closure is safe depends on the individual situation.<sup>2</sup> Wounds that are not closed primarily because of a high risk of infection should be considered for delayed primary closure after 3 to 5 days, when the risk of infection decreases.

## OPTIONS FOR WOUND CLOSURE

The ideal wound closure technique would allow a meticulous wound closure; would be easily and rapidly applied, painless, of low risk to the health care provider, and inexpensive; and would result in minimal scarring with a low infection rate. Sutures are the most commonly used wound closure technique. Tissue adhesives have recently been approved by the FDA and are expected to replace sutures in 25% to 33% of ED laceration repairs and in closure of many surgical incisions.<sup>69</sup> Other alternatives include staples and surgical tapes.

### Sutures

Nonabsorbable sutures, such as nylon and polypropylene (Table 4), retain most of their tensile strength for longer than 60 days, are relatively nonreactive, and are appropriate for closure of the outermost layer of the laceration.<sup>70-72</sup> Removal of nonabsorbable sutures is required.

Absorbable sutures are usually used for closure of structures deeper than the epidermis (Table 5). In general, synthetic absorbable sutures are less reactive and have greater tensile strength than sutures from natural sources, such as catgut. They increase the time during which the healing wound retains 50% of its tensile strength from less than 1 week to as long as 2 months.

**Table 4.**  
*Characteristics of nonabsorbable sutures.*

Suture Material	Knot Security	Tensile Strength	Tissue Reactivity	Workability
Nylon (Ethilon)	Good	Good	Minimal	Good
Polypropylene (Prolene)	Least	Best	Least	Fair
Silk	Best	Least	Most	Best

Chromic gut lasts for up to 2 weeks and is associated with tissue reactivity. Polyglactin and polyglycolic acid maintain tensile strength for 20 to 28 days and are associated with minimal tissue reactivity. Some synthetic absorbable sutures (eg, polydioxanone, polyglyconate) retain their tensile strength for as long as 2 months, making them useful in areas with high dynamic and static tension. Use of these sutures should be limited to deeper structures, because they may become extruded over time.

Deep sutures help relieve skin tension, decrease dead space and hematoma formation, and probably improve cosmetic outcome. Emergency physicians typically review their work in the short term, when patients return for suture removal. This can lead to a false sense of achieving an excellent outcome. As wounds undergo remodeling over the next 3 to 12 months, the scar typically widens, and an excellent short-term outcome does not necessarily predict an excellent long-term cosmetic outcome.<sup>73</sup> Anecdotally, plastic surgeons who observe lacerations for 1 year from the time of primary closure believe that placement of deep sutures with apposition of skin edges before placement of the percutaneous sutures achieves a better long-term cosmetic result. We are unaware of any randomized, controlled clinical trials that have compared long-term cosmetic outcome based on whether the patient did or did not receive deep suture placement. Animal studies suggest that deep sutures should be avoided in highly contaminated wounds, where they increase the risk of infection.<sup>74,75</sup> Deep sutures do not increase the risk of infection in clean, noncontaminated lacerations.<sup>76</sup> We recommend liberal use of deep sutures to approximate skin edges before skin closure with either sutures or tissue adhesives. Sutures through adipose tissue do not hold tension, increase infection rates, and should be avoided.<sup>77</sup>

**Table 5.**  
*Characteristics of absorbable sutures.*

Suture Material	Knot Security	Wound Tensile Strength	Security* (d)	Tissue Reactivity
Surgical gut	Poor	Fair	5–7	Most
Chromic gut	Fair	Fair	10–14	Most
Polyglactin (Vicryl)	Good	Good	30	Minimal
Polyglycolic acid (Dexon)	Best	Good	30	Minimal
Polydioxanone (PDS)	Fair	Best	45–60	Least
Polyglyconate (Maxon)	Fair	Best	45–60	Least

\*Retention of 50% of tensile strength.

The use of lubricated coatings does not appear to affect the infection rate.<sup>78</sup>

Although use of absorbable sutures is generally reserved for subcuticular tissues, rapidly dissolving forms may be used to close the skin in children and thereby avoid the discomfort associated with suture removal.<sup>79</sup> Generally, synthetic and monofilament sutures are preferred over natural and braided sutures because they result in lower rates of infection.<sup>78</sup>

### Staples

Staples can be applied more rapidly than sutures.<sup>80,81</sup> They are associated with a lower rate of foreign body reaction and infection.<sup>80,82,83</sup> Brickman and Lambert<sup>83</sup> used staples in 75 patients with 87 lacerations to the scalp, trunk, and extremities. No patient developed an infection, and only 1 patient had a dehiscence. Ritchie and Rocke<sup>80</sup> performed a randomized, controlled trial comparing sutures with staples for scalp lacerations. They found that lacerations healed equally well, with low infection rates (less than 2%) in both groups. In general, staples are considered particularly useful for scalp,<sup>80,84</sup> trunk, and extremity wounds<sup>2</sup> and when time saving is essential (eg, mass casualties, patients with multiple trauma wounds).<sup>2</sup> However, they do not allow as meticulous a closure as sutures and are slightly more painful to remove.<sup>81</sup> In animal models, staples are associated with lower rates of bacterial growth and lower infection rates than sutures.<sup>82</sup> In clinical series, these effects may be statistically significant but are of limited clinical significance.<sup>84</sup>

### Adhesive tapes

Surgical tapes are even less reactive than staples,<sup>82</sup> but they require the use of adhesive adjuncts (eg, tincture of benzoin) that increase local induration and wound infection.<sup>85</sup> Adhesive adjuncts are toxic to wounds, and care should be taken that they do not enter the wound. Although the various surgical tapes have different degrees of adhesion, porosity, breaking strength, and elasticity,<sup>86</sup> tapes alone cannot maintain wound integrity in areas subject to tension.<sup>87</sup> They are seldom recommended for primary wound closure in the ED<sup>2</sup> but are often used after suture removal to decrease tension on the wound until they fall off.

### Tissue adhesives

Tissue adhesives (n-butylcyanoacrylates) have been in use for several decades in Europe and Canada. 2-Octylcyanoacrylates (eg, Dermabond; Ethicon) were

approved for use in the United States in August of 1998. Within the first month of availability, more than 3 million units of Dermabond were ordered. Tissue adhesives contain cyanoacrylates. They are liquid monomers synthesized by a combination of formaldehyde and cyanoacetate. Shorter alkyl-chain molecules (methyl, ethyl) are more reactive and have greater histotoxicity and weaker tissue binding than longer alkyl-chain cyanoacrylates. In large quantities, they are tissue toxic. The n-butylcyanoacrylates are less toxic than shorter-chain cyanoacrylates and maintain a stronger bond. 2-Octylcyanoacrylate is even more stable, has greater flexibility, and maintains a stronger bond. It has a breaking strength almost 4 times greater than that of the butylcyanoacrylates and degrades much more slowly, leading to its classification as nontoxic.<sup>88</sup>

Monomeric cyanoacrylates polymerize in the presence of hydroxyl ions, which can be found in water and blood, thereby bonding with the skin. It is the ethylene portion of the molecule that polymerizes. Tissue adhesives are for topical use only; they should not be placed within the wound. Application procedures are discussed later.

Two large observational studies in Israel of 331 and 1,500 children with scalp, face, or limb lacerations treated with Histoacryl Blue (Braun, Germany), a butyl-2-cyanoacrylate, demonstrated infection rates of less than 2% and dehiscence rates of 0.6% to 1.8%.<sup>89,90</sup> Quinn et al<sup>91</sup> performed a prospective, randomized trial comparing Histoacryl Blue with 5-0 or 6-0 sutures for repair of small facial lacerations. They found that the 3-month cosmetic outcome, as assessed by review of photographs by plastic surgeons, was equivalent in the 2 groups. The time required for laceration closure and the pain associated with the procedure were significantly less for the tissue adhesive. Simon et al<sup>92</sup> found that the cosmetic outcome was equivalent for Histoacryl Blue and for sutures at 1 year. Subset analysis of their data suggested that small lacerations aligned against lines of minimal tension may benefit most from the use of tissue adhesive rather than sutures.<sup>93</sup>

Clinical studies using 2-octylcyanoacrylate have been conducted in the United States and Canada. Quinn et al<sup>94</sup> evaluated 130 patients who were randomly assigned to receive laceration closure with either 2-octylcyanoacrylate or 5-0 or 6-0 monofilament sutures. Both 3-month and 1-year cosmetic outcomes have been reported.<sup>94,95</sup> In both cases, the cosmetic appearance of the healed lacerations, as judged by review of photographs of the scar by plastic surgeons,

was found to be equivalent. Laceration closure with 2-octylcyanoacrylate was less painful and faster than with sutures.

The largest trial of laceration closure was conducted in the FDA study undertaken for the approval of 2-octylcyanoacrylate (Dermabond). This trial included patients from a variety of different sites, including EDs, pediatric EDs, surgical centers, and facial plastic surgery office-based practices. Patients were randomly assigned to receive skin closure either with 5-0 or 6-0 sutures (or, in rare cases, staples or adhesive tapes) or with 2-octylcyanoacrylate. Short-term assessment included the wound infection and dehiscence rates and an acute inflammation score (erythema, warmth, pain and swelling). Long-term outcome was the 3-month cosmetic outcome using validated cosmetic scales.<sup>3,73,96</sup>

Of the 818 patients enrolled, 333 had subcuticular or subcutaneous sutures placed before laceration closure. Comparing the group of patients who received 2-octylcyanoacrylate with the group who received skin closure with sutures (or, in rare instances, with staples or adhesives tapes), the 3-month cosmetic outcome, short-term infection rate, and wound dehiscence rate were all statistically equivalent. Again, the time to wound closure was more than 50% shorter for the group treated with 2-octylcyanoacrylate.<sup>97</sup>

Although the infection rates were statistically equivalent for the patients who did and did not receive tissue adhesive, the tissue adhesive group had an infection rate of 3.6% and the control group had an infection rate between 1% and 2%. This trend toward an increased infection rate in the tissue adhesive group was not in concert with other data from the same trial. For example, the risk of erythema was considerably reduced in the tissue adhesive group, compared with the control group, and swelling, tenderness, and warmth were equivalent. In addition, *in vivo* studies have found that 2-octylcyanoacrylate tissue adhesive possess antimicrobial properties against gram-positive organisms.<sup>98</sup> A thorough review of the individual cases of infection from both groups has identified the likely explanation. We found that patients who received tissue adhesive skin closure were less likely to receive anesthesia and less likely to have had the wounds cleansed appropriately. This finding reinforces the need to cleanse lacerations before wound closure.

Results of the study in the ED patient population were analogous to those for the group as a whole.<sup>99</sup> Among 124 patients, Singer et al<sup>99</sup> reported excellent 3-month cosmetic outcomes for both groups. More than 80% of

patients had optimal cosmetic scores, as assessed by direct physician observation. In addition, patient satisfaction scores were equivalent in both groups. Likewise, subgroup analysis of the results in a pediatric ED found equivalent cosmetic outcomes at 3 months.<sup>100</sup>

The application of tissue adhesives is rapid and painless, and they do not require suture removal. They usually slough off in 7 to 10 days as the keratinized layer of epithelium sloughs. They should be used only topically, and care should be taken not to place adhesive in the wound or between wound margins. Octylcyanoacrylate provides the greatest 3-dimensional tensile strength of all the cyanoacrylates and is a needleless alternative to sutures for closure of most facial lacerations, providing excellent cosmetic appearance comparable to that achieved with sutures.<sup>94-97,99-102</sup> 2-Octylcyanoacrylate (Dermabond) is packaged in a sterile, single-use ampule and is colored with violet dye. After the inner glass portion of the ampule is manually crushed, the polymerization process begins. The adhesive should be painted on top of the skin as the laceration is manually approximated. If lacerations cannot be manually approximated and skin edges cannot be held together without a lot of tension, the use of tissue adhesives is inappropriate. The clinician should apply at least 3 or 4 coats of 2-octylcyanoacrylate to provide adequate strength to the

wound closure. Care should be taken to avoid applying too much tissue adhesive, because polymerization is associated with heat release (ie, it is an exothermic reaction). Increasing rates and amounts of polymerization may be associated with increased heat sensation by the patient. Proper application of 2-octylcyanoacrylate appears to be easy to learn. In one study, the first applications by physicians on patients had cosmetic outcomes as good as those of subsequent applications.<sup>103</sup>

2-Octylcyanoacrylates can be used in areas of higher tension, but only if subcutaneous or subcuticular absorbable sutures are used to relieve tension on the skin edges. They should not be used over areas that are subject to great tension or repetitive movement (eg, joints, hands). When tissue adhesives result in suboptimal wound closure or must be removed for some other reason, bathing or application of antibiotic ointment or petroleum jelly (Vaseline) may accelerate removal. Acetone can be used when more rapid removal is necessary.

The butylcyanoacrylates have less tensile strength than 5-0 sutures and only one third to one fourth of the tensile strength of the octylcyanoacrylates.<sup>88</sup> They are not currently available in the United States, although clinical trials are ongoing. Studies have found that butylcyanoacrylates are equivalent to 5-0 and 6-0 sutures for the repair of very small lacerations. They are packaged in nonsterile,

**Table 6.**  
*Advantages and disadvantages of the common wound closure techniques.*

Technique	Advantages	Disadvantages
Suture	Time honored Meticulous closure Greatest tensile strength Lowest dehiscence rate	Requires removal Requires anesthesia Greatest tissue reactivity Highest cost Slowest application
Staples	Rapid application Low tissue reactivity Low cost Low risk of needle stick	Less meticulous closure May interfere with some older-generation imaging techniques (computed tomography, magnetic resonance imaging)
Tissue adhesives	Rapid application Patient comfort Resistant to bacterial growth No need for removal Low cost No risk of needle stick	Lower tensile strength than sutures Dehiscence over high-tension areas (joints) Not useful on hands Cannot bathe or swim
Surgical tapes	Least reactive Lowest infection rates Rapid application Patient comfort Low cost No risk of needle stick	Frequently falls off Lower tensile strength than sutures Highest rate of dehiscence Requires use of toxic adjuncts Cannot be used in areas of hair Cannot get wet

multiple-use vials and are applied in beads across the laceration. In general, the butylcyanoacrylates are more brittle and more friable than octylcyanoacrylates and do not allow the same degree of movement and flexibility of the skin. The longer-carbon-chain molecules have more flexibility and are less likely to crack and fall off.

Other advantages of cyanoacrylates are that they act as their own dressing and have antimicrobial effects against gram-positive organisms, with the potential to decrease wound infections when used topically.<sup>98,104</sup> In general cyanoacrylates are less expensive than sutures or staples and are strongly preferred by patients.<sup>105</sup> A summary of the advantages and disadvantages of the various methods for wound closure is presented in Table 6.

### Postoperative care

Sutured or stapled lacerations should be covered with a protective, nonadherent dressing for at least 24 to 48 hours, until enough epithelization takes place to protect the wound from gross contamination.<sup>106</sup>

Maintenance of a moist wound environment has also been shown to speed the rate of re-epithelization in sutured lacerations.<sup>107,108</sup> In addition, it has been suggested that topical antibiotic ointments may help reduce infection rates and prevent scab formation. Although white petrolatum may be as effective as bacitracin in ambulatory surgery patients,<sup>109</sup> topical antibiotics result in lower infection rates in traumatic lacerations.<sup>110</sup> When 2-octylcyanoacrylates are used for laceration closure, topical ointments should not be applied. They loosen the tissue adhesives and may result in dehiscence.

Sutured or stapled wounds should be kept clean and gently cleansed after 24 to 48 hours. Patients with tissue adhesives in place may shower, but they should avoid bathing and swimming. Prolonged moisture loosens the adhesive bond. Gentle blotting to dry the area is preferred to repeated wiping. Elevation of the injured area decreases edema formation. Patients should be instructed to observe the wound for erythema, warmth, swelling, and drainage, because these findings may indicate infection. Use of standardized wound care instructions improves patient compliance and understanding.<sup>111</sup>

Routine use of prophylactic antibiotics is not recommended. Several clinical studies and a meta-analysis all concluded that there is no benefit to use of prophylactic antibiotics for routine laceration repair.<sup>112-116</sup> Use of antibiotics should be individualized based on the degree of bacterial contamination, the presence of infection-potentiating factors (eg, soil), the mechanism of injury,

and host factors, as discussed previously.<sup>69</sup> In general decontamination is far more important than antibiotics. Antibiotic use should be reserved for most human, dog, and cat bites and for intraoral lacerations, open fractures, and exposed joints or tendons.<sup>2,117,118</sup>

Sutures or staples over most areas of the body should be removed after approximately 7 days. Facial sutures should be removed sooner (within 3 to 5 days) to avoid formation of unsightly sinus tracts. Sutures subject to large tension forces, such as over joints and on the hand, should be left in for 10 to 14 days. When 2-octylcyanoacrylate is used, care should be taken to avoid picking or scrubbing of the area or exposure to water for more than brief periods.

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