

*Current Concepts*EVALUATION AND MANAGEMENT
OF TRAUMATIC LACERATIONSADAM J. SINGER, M.D., JUDD E. HOLLANDER, M.D.,
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EACH year in the United States, more than 12 million traumatic wounds are treated in emergency departments.¹ When nonemergency or elective incisions are included, approximately 90 million skin-suturing procedures are performed each year.² Traumatic lacerations occur most often in young men, typically on the face, scalp, and hands.³ More than 50 percent of all lacerations are caused by blunt injury that produces shear forces, and most others by sharp objects, such as metal, glass, and wood.^{3,4} Only a minority of wounds are caused by mammalian or nonmammalian bites.³

The ultimate goals of wound management are to avoid infection and achieve a functional and cosmetically acceptable scar. Although death from traumatic wounds is rare, their improper management may lead to wound infection as well as unsightly and dysfunctional scars. The identification of host and environmental factors that increase the likelihood of a poor outcome, as well as the appropriate preparation and timely, meticulous closure of wounds, will help achieve these goals.

EVALUATION OF PATIENTS

Proper wound management begins with a thorough history of the patient. Particular attention should be paid to the factors that can affect wound healing adversely. Host factors such as extreme older and younger age, diabetes mellitus, chronic renal failure, obesity, malnutrition, and the use of immunosuppressive medications, such as corticosteroids and chemotherapeutic agents, all increase the risk of infection and can impair wound healing.⁵ Healing may also be impaired in inherited and acquired connective-tissue disorders, such as the Ehlers-Danlos syndrome, Marfan's syndrome, osteogenesis imper-

fecta, and protein and vitamin C deficiencies. The tendency of the patient to form keloids should be ascertained, because this may result in a poor scar. Keloids extend beyond the boundaries of the original injury and are largely determined by genetic or racial predisposition. Conversely, hypertrophic scars, which remain within the boundaries of the original injury, usually result from a tissue deficiency or from the fact that the wounds are not parallel to the lines of minimal skin tension.

Anatomical variation in regional blood flow and skin flora also play a part in determining the likelihood of infection. Wounds located on the highly vascularized face or scalp are less likely to be infected than wounds in less vascularized areas.³ The location of the wound also contributes to the cosmetic appearance of the scar by affecting static and dynamic skin tensions.⁶ Thus, lacerations over joints, which are subject to large dynamic skin tensions, are prone to the development of wider scars, as are wounds that run perpendicular to the lines of minimal skin tension.

Although most wounds are caused by shear forces, compressive forces cause more devitalization of tissue, and therefore crush wounds are more susceptible to infection.⁷ Finally, whether the patient is allergic to local anesthetics, latex, or antibiotics should be determined. All patients should have their tetanus status assessed and should be immunized in accordance with the recommendations of the Centers for Disease Control and Prevention (Table 1).

EXAMINATION OF THE WOUND

Adherence to sterile techniques is recommended, although studies supporting this practice are lacking.⁸⁻¹⁰ The wound should be examined meticulously in all cases. Proper lighting and control of bleeding are required to identify foreign bodies and any injury to vital structures (such as nerves and tendons). Wounds over joints and tendons should be put through a full range of motion, since their position during the injury may differ from their position during the examination. A detailed neurovascular examination should be performed and documented before anesthesia and closure. Perfusion should be assessed by palpation of pulses and capillary refill distal to the injury. Motor and sensory evaluation should be based on a thorough understanding of the regional anatomy and should include a functional assessment of all muscles traversing the injured area. Two-point discrimination (the ability to discriminate one from two stimuli) should be assessed in injuries involving the hands or fingers.

A common mistake is the failure to identify and recognize the need for surgical exploration in the operating room. Patients with proved or suspected involvement of joints, nerves, or flexor tendons may be better served by repair in the operating room.

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TABLE 1. RECOMMENDATIONS FOR PROPHYLAXIS AGAINST TETANUS.

HISTORY OF TETANUS IMMUNIZATION	AFTER CLEAN, MINOR WOUNDS		AFTER ALL OTHER WOUNDS*	
	TETANUS-DIPHtheria TOXOID	TETANUS IMMUNE GLOBULIN	TETANUS-DIPHtheria TOXOID	TETANUS IMMUNE GLOBULIN
No. of previous doses <3 or not known	Yes	No	Yes	Yes
No. of previous doses ≥ 3				
Timing of last dose				
Within 5 yr	No	No	No	No
Within 5 to 10 yr	No	No	Yes	No
>10 yr ago	Yes	No	Yes	No

*Examples of these include contaminated wounds, puncture wounds, avulsions, burns, and crush injuries.

TABLE 2. PROPERTIES OF COMMONLY USED LOCAL ANESTHETIC AGENTS.*

AGENT	TRADE NAME	CLASS	RECOMMENDED CONCENTRATION	MAXIMAL SAFE DOSE	DURATION OF ACTION
			percent	mg/kg	
Procaine with epinephrine	Novocain	Ester	0.5–1.0	7	15–45 min
				9	30–90 min
Lidocaine with epinephrine	Xylocaine	Amide	0.5–2.0	4.5	1–2 hr
				7	2–4 hr
Bupivacaine with epinephrine	Marcaine	Amide	0.125–0.25	2	4–8 hr
				3	8–16 hr

*Anesthesia occurs after two to five minutes with the agents shown.

WOUND PREPARATION

Anesthesia

Proper wound preparation requires adequate anesthesia. Local anesthetic agents may be classified as amides or esters (Table 2). Allergic reactions to these agents are rare and are usually due to preservatives (such as methylparaben). Patients with known allergies to a specific local anesthetic from one of the groups (for example, procaine) can be treated with an agent from the other group (for example, lidocaine). The use of pure agents without preservatives (for example, cardiac lidocaine) further reduces the risk of an allergic reaction. Diphenhydramine may be used for the rare patient who is allergic to an unknown local anesthetic agent.¹¹ Long-acting agents, such as bupivacaine, should be considered for lacerations when extended pain relief may be required.

Anesthetic agents are most often administered by local infiltration. There are several ways to reduce the pain associated with local infiltration: adding sodium bicarbonate to the local anesthetic; using warm solutions of anesthetic, small needles, and

slow rates of infiltration; injecting the agent through the edges of the wound when the wound is not contaminated; and pretreating the wound with topical anesthetics.^{12–15} The change in the local pH of the wound due to buffering does not increase the likelihood of infection.¹⁶

Alternative methods of anesthesia include topical application and regional nerve blocks. Topical anesthetics may avoid the need for infiltrative anesthesia, especially in highly vascular facial and scalp lacerations. Although the combination of tetracaine, adrenaline, and cocaine has been most commonly used, the associated complications (e.g., seizures, death, or both) have led to the development of alternative combinations. A combination of lidocaine, adrenaline, and tetracaine has been shown to be as effective, without the associated risks.¹⁷ Regional anesthesia should be used for large wounds that would otherwise require large, potentially toxic doses of local anesthetics; wounds in which undesirable tissue distortion would result from local infiltration; and wounds in which local infiltration would be particularly painful (for example, those on the plantar surface of the foot). The addition of a vasoconstricting

TABLE 3. CHARACTERISTICS OF ABSORBABLE AND NONABSORBABLE SUTURES.

TYPE OF SUTURE (TRADE NAME)	DEGREE OF KNOT SECURITY	TENSILE STRENGTH	DURATION OF WOUND SECURITY*	TISSUE REACTIVITY
Absorbable				
Surgical gut	Poor	Fair	5–7 days	Most
Chromic gut	Fair	Fair	10–14 days	Most
Polyglactin (Vicryl)	Good	Good	30 days	Minimal
Polyglycolic acid (Dexon)	Best	Good	30 days	Minimal
Polydioxanone (PDS)	Fair	Best	45–60 days	Least
Polyglyconate (Maxon)	Fair	Best	45–60 days	Least
Nonabsorbable				
Nylon (Ethilon)	Good	Good	NA	Minimal
Polypropylene (Prolene)	Least	Best	NA	Least
Silk	Best	Least	NA	Most

*This column indicates the period during which at least 50 percent tensile strength is retained. NA denotes not applicable.

agent such as epinephrine to the local anesthetic allows a higher dose to be administered, prolongs the duration of action, and helps control local bleeding. However, the use of vasoconstrictors should be avoided in areas with end arterioles, such as the fingers, toes, penis, and tip of the nose. With very young or uncooperative patients, conscious sedation that follows accepted guidelines may be required.¹⁸

Hair Removal

Hair is a source of contamination and may complicate wound closure. It may be removed by clipping. Shaving wounds hair follicles, allowing access to bacteria, and may therefore increase infection rates.¹⁹ Hair should not be removed over the eyebrows, since this may result in abnormal regrowth.

Irrigation

Proper irrigation reduces bacterial contamination and helps prevent infection, because any soil or small foreign bodies that remain reduce the inoculum of bacteria required to produce infection.^{20–23} Although the optimal irrigation pressure is unknown, most authorities recommend high-pressure irrigation, with impact pressures on the wound in the range of 5 to 8 lb per square inch.⁴ This pressure may be achieved by using a 35- or 65-ml syringe and a 16- or 19-gauge needle.^{21,24} Higher pressures may increase trauma to the tissue and should be reserved for highly contaminated wounds.²⁵ Using a plastic shield at the end of the irrigating syringe decreases splatter and occupational hazards.

Although many types of fluids have been studied, saline remains the most readily available, economical, and effective irrigant.²⁶ Concentrated povidone-iodine, hydrogen peroxide, and detergents may cause substantial tissue toxicity and should be avoided.^{27,28}

Débridement

Any devitalized tissue such as fat, muscle, and skin that remains further impairs the ability to resist infection.^{4,29} Therefore, removing all such tissue mechanically and surgically is an essential part of wound management. Mechanical débridement may be performed by surgical excision, scrubbing with a surgical sponge, or high-pressure irrigation.

Wound Closure

Most wounds should have primary closure (immediate approximation of wound edges) to reduce the patient's discomfort and speed healing. There is a direct relation between the time from the injury to closure of the laceration and the risk of subsequent infection, but the length of this "golden period" is highly variable.³⁰ Wounds at low risk for infection can be closed 12 to 24 hours after the injury, but for wounds at high risk (contaminated wounds, those in locations with poor vascular supply, and those in immunocompromised patients), primary closure should take place within approximately 6 hours. Thus, the time during which wound closure is safe needs to be tailored individually on the basis of causation, location, and host factors. When wounds are not closed because of a high risk of infection, delayed primary closure should be considered after three to five days, when the risk of infection decreases, especially if they are large, may have a poor cosmetic outcome, or are associated with discomfort or inconvenience.

Sutures are the most commonly used method of wound closure. Alternatives include staples, adhesives, and surgical tapes. The specific choice of material for closure depends on the intended function, the location of the wound, and the preference of the practitioner.

Nonabsorbable sutures (Table 3), such as those of

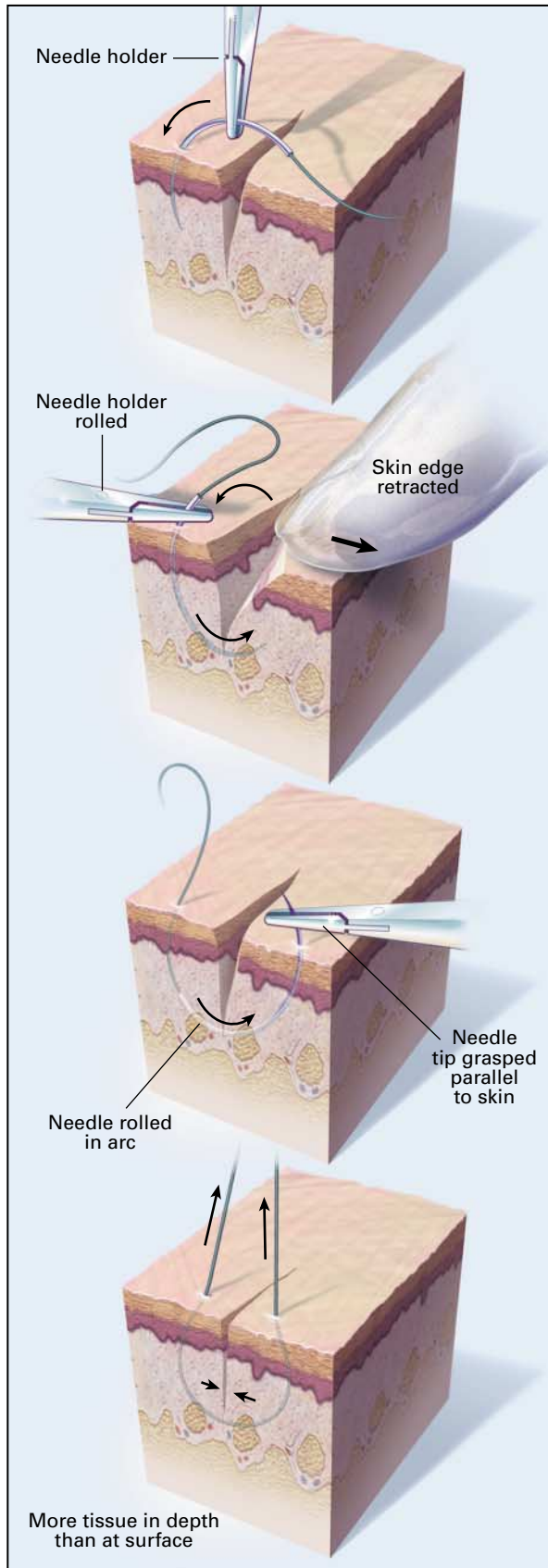


Figure 1. Placement of a Simple Suture.

When the needle is held upside down and the wrist pronated, the needle tip moves farther away from the laceration and penetrates deeply. Thus, there is more tissue at the depth of the wound, causing eversion of the wound. The needle should enter the skin at 90 degrees. Adapted from Singer et al.,³⁶ with the permission of the publisher.

nylon and polypropylene, retain most of their tensile strength for more than 60 days, are relatively nonreactive, and are appropriate for closing the outermost layer of the laceration.³¹ Nonabsorbable sutures must be removed. By contrast, absorbable sutures are usually used to close structures deeper than the epidermis (Table 3). Synthetic absorbable sutures are less reactive and have more tensile strength than sutures made from natural sources, such as catgut. Some synthetic absorbable sutures, such as those made of polydioxanone and polyglyconate, retain their tensile strength for long periods, making them useful in areas with high dynamic and static tensions. The use of these sutures should be limited to deeper structures, since they may become extruded over time.

Although the use of absorbable sutures is generally reserved for the subcuticular tissues, rapidly dissolving forms of such sutures can be used to close skin in children in order to avoid the discomfort associated with suture removal. Generally, synthetic and monofilament sutures are preferable to natural and braided sutures, since they are associated with lower infection rates.³²

Deep sutures help relieve skin tension, decrease dead space and the formation of hematomas, and may improve the cosmetic outcome by reducing the width of the scar. They should be used when multilayered closure is preferred, as to close the frontalis muscle in the forehead. However, they should be avoided in highly contaminated wounds, because they will increase the risk of infection.³³ Sutures through adipose tissue do not hold tension and increase infection rates.³⁴ Therefore, they should be avoided. In patients with a history of keloid formation, the skin should be closed with minimal tension, and the use of pressure dressings for three to six months should be considered, to reduce keloid formation.³⁵

Optimal cosmetic results require attention to several important technical principles. The proper placement of sutures should result in slight eversion of the wound, so that remodeling will not result in a depressed scar (Fig. 1). Sutures should be tied tightly enough to approximate the wound edges, but not so tightly that they cause tissue necrosis due to swelling. When deep sutures are used to minimize skin tension, the knots should be buried (Fig. 2).

Staples can be applied more rapidly than sutures^{37,38} and are associated with a lower rate of reaction to foreign bodies and subsequent infection.^{37,39} They

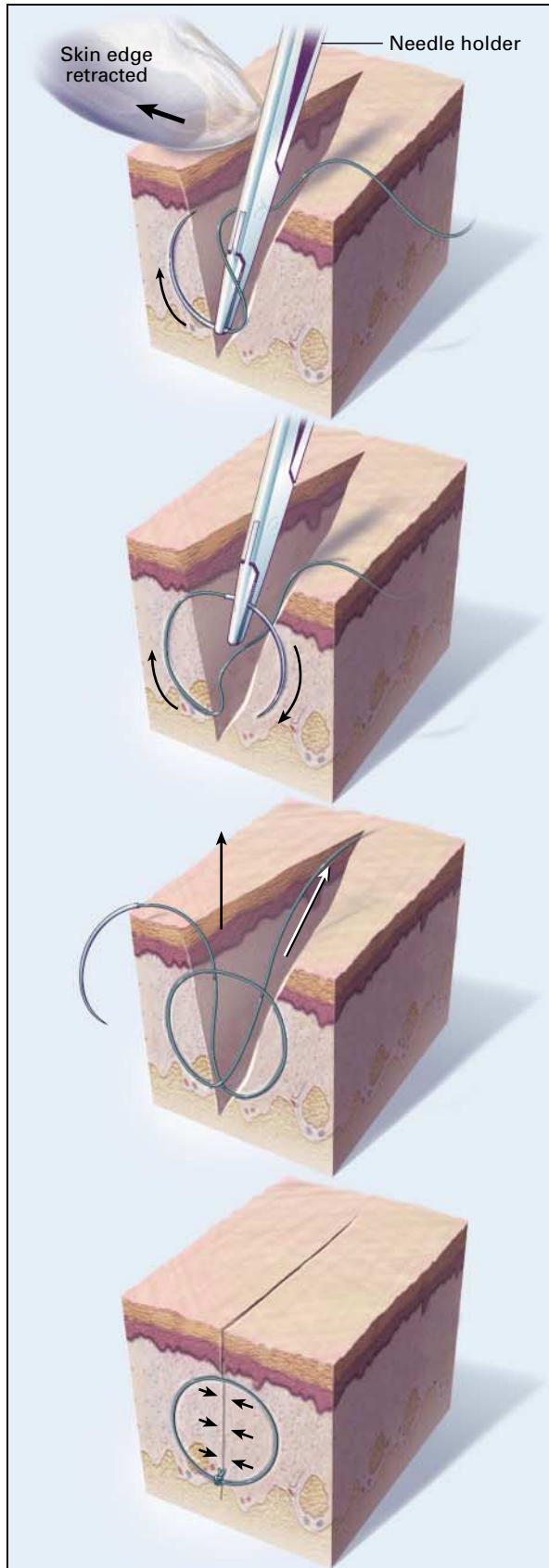


Figure 2. Placement of a Deep Suture.

The needle is first inserted at the depth of the wound and removed closer to the skin surface. The needle is then inserted superficially into the opposite side of the wound and exits deeply so that the knot is buried deep within the wound.

are particularly useful for wounds of the scalp,³⁷ trunk, and extremities, and when saving time is essential, as in treating mass casualties and victims of multiple trauma. However, they do not allow as meticulous a closure as sutures and are slightly more painful to remove.³⁸ Surgical tape is even less reactive than staples,³⁹ but it requires the use of adhesive adjuncts (for example, tincture of benzoin) that increase the likelihood of local induration and wound infection.⁴⁰ Tape alone will not maintain wound integrity in areas subject to tension.⁴¹

Tissue adhesives, such as cyanoacrylates, have been used for several decades in Europe and Canada. They are currently under review by the Food and Drug Administration (FDA) for use in the United States. Their application is rapid and painless, and they do not require suture removal because they slough off in 7 to 10 days. They should only be used topically, and care should be taken not to place adhesive in the wound or between its margins. Octylcyanoacrylate has the greatest three-dimensional tensile strength of all the cyanoacrylates and is a needle-free alternative to sutures for the closure of most facial lacerations, providing an excellent cosmetic result, similar to that achieved with sutures.⁴²⁻⁴⁵ Cyanoacrylates can be used on other areas of the body, but they usually require deep absorbable sutures, since their breaking strength is less than that of most sutures. They should not be used in areas subject to great tension or repetitive movement, such as joints or hands. Other advantages of cyanoacrylates are that they act as their own dressing and have antimicrobial effects against gram-positive organisms and the potential to decrease the rate of wound infection.^{46,47} In general, cyanoacrylates are less expensive than sutures and staples, and patients prefer them.⁴⁸ The advantages and disadvantages of the various methods of wound closure are summarized in Table 4.

Postoperative Care

Patients should be instructed to keep their wounds clean. Most wounds should be covered with a protective, nonadherent dressing for at least 24 to 48 hours, until there is enough epithelialization to protect the wound from gross contamination.⁴⁹ Maintaining a moist environment around the wound has also been shown to speed the rate of epithelialization.^{50,51} After this period, patients may wash their wounds but should not scrub or soak them. Apply-

TABLE 4. ADVANTAGES AND DISADVANTAGES OF COMMON TECHNIQUES OF WOUND CLOSURE.

TECHNIQUE	ADVANTAGES	DISADVANTAGES
Sutures	Time-honored method Meticulous closure Greatest tensile strength Lowest dehiscence rate	Removal required Anesthesia required Greatest tissue reactivity Highest cost Slowness of application
Staples	Rapidity of application Low tissue reactivity Low cost Low risk of needle stick	Less meticulous closure than with sutures May interfere with computed tomography and magnetic resonance imaging
Tissue adhesives	Rapidity of application Patient comfort Resistance 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)
Surgical tapes	Least tissue reactivity Lowest infection rates Rapidity of application Patient comfort Low cost No risk of needle stick	Lower tensile strength than sutures Highest rate of dehiscence Use of toxic adjuncts required Cannot be used in hairy areas Must remain dry

ing topical antibiotic ointments may help reduce infection rates and prevent scab formation.⁵² Keeping the injured area elevated decreases edema. Patients should be instructed to observe their wounds for the erythema, warmth, swelling, and drainage that may indicate infection. Using standardized instructions for wound care improves patients' compliance and understanding.⁵³

The routine use of prophylactic antibiotics is not recommended.⁵⁴ Antibiotic use should be tailored to the individual on the basis of the degree of bacterial contamination, the presence of infection-potentiating factors, such as soil, and the mechanism of injury, as well as the host factors discussed above. In general, decontamination is far more important than using antibiotics. Antibiotics should be reserved for most human, dog, and cat bites, as well as for intraoral lacerations, open fractures, and exposed joints or tendons.^{55,56} Open fractures and exposed joints or tendons should receive coverage for staphylococci and streptococci, usually with a first-generation cephalosporin or a penicillinase-resistant penicillin. Additional gram-negative coverage with an aminoglycoside should be considered in the case of heavily contaminated open fractures. Dog and cat bites, which commonly contain *Pasteurella multocida* as well as staphylococci and streptococci, can be treated prophylactically with a broad-spectrum antibiotic, such as amoxicillin with clavulanic acid. Human bites, which may contain *Eikenella corrodens* in addition to staphylococci and streptococci, can be similarly treated.

Careful attention should be paid to the timing of

suture removal. Sutures or staples in most areas of the body should be removed after approximately seven days. Facial sutures should be removed sooner (within three to five days) to avoid the formation of unsightly sinus tracts. Sutures subject to considerable tension, such as those over joints and on the hands, should be left in for 10 to 14 days. After the removal of the sutures, the wounds should be reinforced with surgical adhesives or tapes to prevent dehiscence. It is important that both patients and physicians understand that the appearance of the scar may change substantially during the year after the repair. Patients should avoid exposing the wound to sun to reduce the likelihood of complications such as hyperpigmentation. Any consideration given to scar revision should await the remodeling of the scar over this period.

Future Prospects

With the impending approval of octylcyanoacrylates by the FDA, tissue adhesives should soon be available for use in the United States. Advances in research on the biology of various growth factors could be followed by their introduction into clinical use, and they may be able to increase the speed of healing and decrease scar formation.⁵⁷

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