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Wound Care

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Introduction

The goal of wound care is a healed wound with the best functional and aesthetic outcome. This chapter addresses the key considerations of wound preparation, closure, adjunctive treatments, postoperative wound care; and potential complications.

Wound Preparation

Examination

Wounds are the result of local trauma and can distract the health-care provider from life-threatening injuries. Follow trauma protocols by assessing the ABCs (airway, breathing, and circulation) first and addressing life-threatening injuries before wound care. Wear gloves, eye protection, and a mask to protect against body fluids. Once a primary survey has been performed, obtain a complete history and perform a thorough physical examination, paying special attention to both the local wound environment and systemic factors that may affect wound healing. Evaluate the wound to determine the extent and complexity of injury, the tissues involved, the presence of foreign bodies contamination, and the degree of any previous injury. Note the wound size, location, bleeding, arterial or venous insufficiency, motor and sensory function, tissue temperature, and tissue viability. It may be necessary to probe ducts (e.g., the parotid duct or the lacrimal duct) to assess disruption. Radiographs may be required to rule out underlying bony injuries or retained foreign bodies.

Anesthesia

Anesthesia enables thorough irrigation, debridement, and optimal closure. Much can be accomplished under local anesthetic. While an anesthetic agent may be injected directly into the wound, it may be less reliable in inflamed or infected tissues and can distort anatomic landmarks used to align wound edges. Wherever possible, consider regional nerve blocks outside the zone of injury. Sedation or general anesthesia may be necessary if the patient is unable to tolerate local anesthesia (e.g., young children); the wound requires significant debridement, exploration, or repair; bleeding is difficult to control; or the required local anesthetic dose exceeds the maximum safe dose.

Local anesthetics are broadly divided into amides and esters. Amides (e.g., lidocaine, bupivacaine, and mepivacaine) rarely cause allergic reactions, whereas esters (e.g., tetracaine, procaine, and benzocaine) are metabolized to para-aminobenzoic acid, an allergen to some people. Lidocaine is the most commonly used local anesthetic because of its rapid onset of action (< 2 minutes), duration of action (60–120 minutes), relative safety in comparison to bupivacaine, and availability in multiple forms (e.g., liquid, gel, and ointment) and concentrations (e.g., 0.5%, 1.0%, and 2.0%). The addition of epinephrine to a local anesthetic (dilution of 1:100,000 or 1:200,000) produces vasoconstriction, aids in hemostasis, prolongs the anesthetic's duration of action, and allows a larger dose to be safely administered. Traditionally, local anesthetics with epinephrine have not been used in finger, toe, nose, ear, and genital wounds because of a theoretical risk of ischemia. Nevertheless, these adverse effects have not been documented by prospective studies and use is safe in these anatomical regions.¹

Toxic levels of local anesthetics produce central nervous system effects such as vertigo, tinnitus, sedation, and seizures. These systemic toxicities may progress to cardiovascular effects such as hypotension, arrhythmias, and cardiovascular collapse. Treatment of an overdose is supportive, with oxygen, airway support, and, if necessary, cardiovascular bypass. The maximum safe dose of lidocaine without epinephrine is 3–5 mg/kg and 7 mg/kg with epinephrine. Aspirate before injecting to avoid intravascular injection. To minimize pain, buffer with sodium bicarbonate (1:10 ratio of sodium bicarbonate to local anesthetic), pretreat with a topical anesthetic (e.g., EMLA—a eutectic mixture of lidocaine and prilocaine), use a small-caliber needle (27- or 30-gauge), inject slowly, deliver subcutaneously rather than intradermally, and provide counterirritation.

Irrigation and Debridement

To promote healing and reduce the risk of infection, irrigate and debride necrotic tissue, foreign bodies, and contamination. First expose the wound and the surrounding local tissue. Trim hair with scissors or an electric clipper or retract with ointment. Avoid shaving with a razor because it potentiates wound infection. Avoid clipping eyebrows because they may not grow back and they aid in wound edge alignment. Prepare the surrounding skin with an antibacterial solution such as povidone iodine or chlorhexidine to help create a sterile field and limit contamination.

Irrigation methods include bulb syringe, gravity flow, and pulsatile lavage. These can be further divided into high-pressure (35–70 psi) and low-pressure (1–15 psi) systems. High-pressure pulsatile lavage reduces bacterial concentrations more effectively than low-pressure systems, but can cause more soft tissue disruption and penetration of bacteria into soft tissue. Merely running saline over a wound is of little value. To obtain continuous irrigation with effective pressures of 5–8 psi, wrap a saline bag in a blood pressure cuff, inflate to 400 mmHg, and connect the tubing to a 19-gauge angiocatheter.² Use nontoxic solutions (e.g., saline, lactated Ringer's solution, sterile water, or tap water). Irrigating with an antibiotic solution offers no advantages.

Sharply debride nonviable tissue and firmly embedded foreign bodies. If a significant quantity of questionably viable tissue precludes acute debridement and definitive wound closure, initiate dressing changes and delay wound closure. The wound can be closed when the tissue is declared to be either viable or necrotic and the necrotic tissue debrided.

Hemostasis

Hemostasis prevents hematoma formation, which increases the risk of infection and wound inflammation. Control hemorrhage with pressure, packing, wrapping, and elevating. Almost all bleeding can be controlled with prolonged directed pressure. If absolutely necessary, briefly apply a tourniquet to an injured extremity, but be aware that this is painful and may threaten the extremity. Stop hemorrhage with focused cauterization or vessel ligation. Do not blindly clamp or ligate vessels proximal to amputated parts, because an intact vessel is necessary for microsurgical replantation. Place drains if there is a risk of hematoma or fluid collection, but these are not a replacement for meticulous hemostasis.

Wound Closure

Materials

Following wound preparation, choose the appropriate materials for wound closure. Selection is based on tissue layer as well as wound type and location, potential for infection, the patient's ability to tolerate closure, and the degree of wound tension. Options for soft tissue closure include sutures, staples, tapes, and glues. Some wounds may require the consultation of a specialist surgeon, such as those with open bone fractures, or disrupted tendons or nerves.

Most soft tissues are closed with sutures. Sutures are categorized on the basis of material, tensile strength, filament, absorbability, and time to degradation (Table 36.1). Suture material may be either natural or synthetic. Natural fibers (e.g., catgut, cotton, and silk) cause more inflammatory reaction than synthetic fibers (e.g., polyglycolic acid, nylon, and polypropylene). Suture is a foreign body, which may generate an inflammatory response, interfere with wound healing, and increase infection risk. The number and diameter of sutures used to close a wound should be kept to the minimum necessary for wound edge coaptation.

Suture must support the wound until the tensile strength of the scar can withstand the wound tension. Tensile strength is defined

as the amount of weight required to break a suture divided by the suture's cross-sectional area. It is typically expressed in an integer-hyphen-zero form. Larger integers correspond to smaller suture diameters. For example, a 3-0 suture is twice as heavy as a 4-0 suture. Suture material may be composed of either a monofilament (e.g., catgut, polydioxanone, and polyglyconate) or multifilaments (e.g., polyglycolic acid, polyglactic acid, and polyester). The interstices of multifilament suture may harbor organisms and increase the risk of infection. Nevertheless, multifilament suture is easier to handle, has less memory, and holds knots better than monofilament. Monofilament requires five knots for security, while multifilament may require only three or four knots. Knots must be square to be secure and must be only tight enough to coapt the wound edges but not strangulate the tissue. To minimize foreign body bulk and the risk of protuberance, cut buried suture ends near the knot.

Some suture materials are absorbable while others are permanent. Absorption of synthetic material (e.g., polyglycolic acid, polyglactic acid, and polydioxanone) occurs by hydrolysis and causes less tissue reaction than absorption of natural material (e.g., catgut), which occurs by proteolysis. Absorbable sutures are generally used to approximate dermis and superficial fascia.

Muscle lacerations should be repaired because muscle is capable of a significant restoration of strength. Approximate tendon lacerations to allow gliding and restore tensile strength. Either 3-0 or 4-0 multifilament polyester or monofilament polypropylene is a reasonable choice for muscle and tendon repair. Coapt the epineurium of severed nerves with tension-free primary repair using 8-0 to 10-0 monofilament nylon or repair with a nerve graft or nerve tube. Close deep fascial layers that contribute to the structural integrity of areas such as the abdomen, chest, and galea with 2-0 or 3-0 suture to prevent hernias, structural deformities, and hematomas.

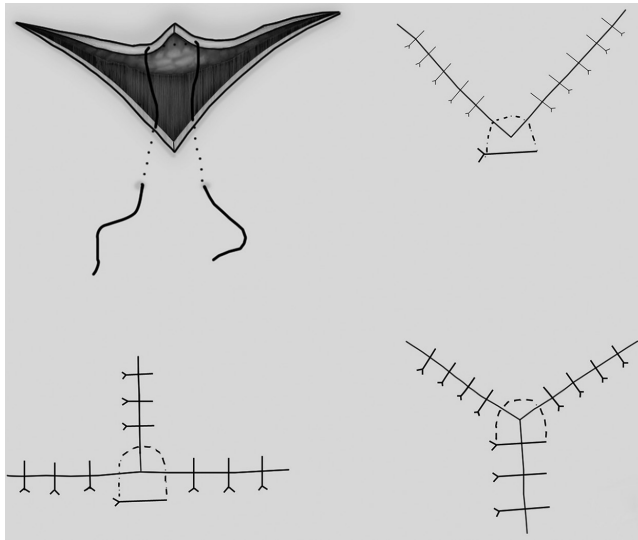
The dermis is responsible for wound strength at the skin level and is usually closed with 4-0 suture. Sutures in the subcutaneous fat do little to aid in strength of the repair. Fat cannot hold sutures by itself, it has a poor blood supply, and suturing may lead to fat necrosis. If necessary for obliteration of dead space, place sutures at the fat-superficial fascia junction or the fat-dermis junction rather than in fat. Bury the dermal sutures and place 5–8 mm apart, with care taken to evert the skin edges. Nonabsorbable sutures (e.g., nylon, silk, or polyester) are most commonly used for the skin surface or deeper structures that require prolonged support (e.g., abdominal wall fascia, tendons, nerves, and blood vessels). For children, suture removal can be both emotionally and physically traumatic. Accordingly, consider using fast-absorbing suture material or a pullout continuous subcuticular suture in young children. At the skin surface, use fine sutures, staples, tapes, or adhesives to facilitate precise alignment. Evert skin edges with 4-0 to 6-0 nylon or polypropylene placed in the superficial dermis and the epidermis. The distance between the sutures and the distance between the wound edge and the suture insertion point should be equal to the thickness of the skin (epidermis and dermis combined).

Skin suturing technique varies depending on the nature of the wound. Simple interrupted sutures are useful for irregular wounds. Vertical and horizontal mattress sutures achieve good wound-edge eversion but can lead to ischemia and thus must not

TABLE 36.1

Suture materials and characteristics

Absorption	Material	Comment	Configuration	Tensile Strength at 2 Weeks (%)	Time to Degradation (days)
Absorbable	Plain catgut (bovine intestinal serosa)	Natural; high tissue reactivity	Monofilament	0	10–14
	Chromic catgut	Natural; treated with chromic acid, less reactive than plain	Monofilament	0	21
	Fast-absorbing catgut	Natural; heat treated	Monofilament	0	7–10
	Polyglytone 6211 (Caprosyn)	Synthetic	Monofilament	10	56
	Glycomer 631 (Biosyn)	Synthetic	Monofilament	75	90–110
	Polyglycolic acid (Dexon)	Synthetic	Mono/multifilament	20	90–120
	Polyglactic acid (Vicryl)	Synthetic	Multifilament	20	60–90
	Polyglyconate (Maxon)	Synthetic	Monofilament	81	180–210
	Polyglycolide (Polysorb)	Synthetic	Multifilament	80	56–70
	Polydioxanone (PDS)	Synthetic	Monofilament	74	180
	Polyglcaprone 25 (Monocryl)	Synthetic	Monofilament	25	90–120
	Polyglactin 910 (Vicryl RAPIDE)	Synthetic	Monofilament	0	7–14
	Polybutester (Novafil)	Synthetic; little tissue reactivity; elastic; good knot security	Monofilament	High	—
	Nylon (Monosof, Dermalon, Ethilon)	Synthetic; little tissue reactivity; memory necessitates more knots	Monofilament	High	—
Nylon (Nurolon)	Synthetic; limited tissue reactivity	Multifilament	High	—	
Nylon (Surgilon)	Synthetic; silicon coated; limited tissue reactivity	Multifilament	High	—	
Polypropylene (Prolene, Surgilene, Surgipro)	Synthetic; limited tissue reactivity; slippery	Monofilament	High	—	
Polyethylene (Dermalene)	Synthetic	Monofilament	High	—	
Stainless steel	Least tissue reactivity; poor handling; artifact on CT scan; moves with MRI	Mono/multifilament	Highest	—	
Nonabsorbable	Cotton	Natural	Multifilament	—	—
	Silk (Sofsilks)	Natural; extensive tissue reactivity; good knot security	Multifilament	Poor	—
	Polyester (Dacron, Mersilene, Surgidac)	Synthetic; high friction; limited tissue reactivity; poor knot security	Multifilament	High	—
	Polyester (Ticron)	Synthetic; silicon coated; limited tissue reactivity; good knot security	Multifilament	High	—
	Polyester (Ethibond)	Synthetic; polybutylate coated; limited tissue reactivity; good knot security	Multifilament	High	—
	Polyester (Ethiflex, Tevdek)	Synthetic; teflon coated; limited tissue reactivity; good knot security	Multifilament	High	—



Method of insertion and application of the three-point suture

FIGURE 36.1 Three-point suture. Figure created by Bin Song, MD, PhD.

be too tight. Half-buried horizontal and vertical mattress sutures are used for flap edges to minimize ischemia. For clean and linear wounds, a continuous intradermal or subcuticular suture is easy to remove and relatively inconspicuous without additional puncture wounds. Flap tips should be sutured with a three-point method to prevent strangulation (Figure 36.1).

Staple closure is less expensive and significantly faster than suture closure, and may provide a better aesthetic outcome for scalp wounds. Contaminated wounds closed with staples have a lower incidence of infection than those closed with sutures.³ When used as the sole method of closure, staples eliminate the risk of a needlestick to the healthcare provider, which is an important consideration in caring for a patient with an unknown medical history. Staples do leave scars at their puncture sites, making them a poor choice for aesthetically sensitive areas such as the face.

Adhesive tapes (e.g., Steri-Strip) are hypoallergenic, have a long shelf life, and are porous. Superficial linear wounds in areas with little tension are easily approximated with tape alone. Tape spares discomfort associated with suture removal, prevents suture puncture scars, and avoids the emotional distress of suturing wounds on children. Advantages include wound edge immobilization, technical simplicity, comfort for the patient, minimal trauma, and lower infection rates in contaminated wounds than suture closure.⁴ Disadvantages include the possibility of inadvertent removal and imprecise wound edge approximation. In addition, tape will not adhere to mobile areas under tension (e.g., the plantar aspects of the feet) or to moist areas (e.g., mucous membranes and groin creases). Wound edema can lead to blistering at the tape margins and to inversion of taped wound edges.

Tissue adhesives (e.g., octylcyanoacrylate) are a fast, strong, and flexible method of approximating wound edges. Compared with sutures, staples, and tapes, adhesive closure is faster and essentially equivalent in terms of aesthetic outcome, infection rate, and dehiscence rate for superficial lacerations.⁵ Adhesives

can be used on most parts of the body and on long wounds. Advantages include low cost, ease of application, and no need for needles or suture removal; their major disadvantage is lack of strength. Do not apply them to tissues within wounds but, rather, apply to intact skin at the wound edges, where they act to hold injured surfaces together. Tissue adhesives are not suitable for wounds in mucous membranes, contaminated wounds, deep wounds, or wounds under tension. Adhesives are particularly useful for superficial wounds or wounds in which the deep dermis has been closed with sutures.

Timing

The decision of when to close a wound may be critical in preventing infection while optimizing aesthetics. Choices include: 1) close the wound at the time of initial presentation (primary closure), 2) delay closure until after a period of healing or wound care (delayed primary closure), or 3) allow the wound to heal on its own (secondary closure). The decision depends whether the patient is stable and able to undergo wound repair, whether nonviable tissue has been adequately debrided and foreign bodies removed, whether and to what degree bacterial contamination is present, and what the expected aesthetic outcome of immediate closure might be in comparison with that of delayed closure or secondary healing.

Primary closure provides optimal wound healing when two perpendicular, well-vascularized wound edges are approximated without tension. Scars are better tolerated than disruption of anatomic landmarks. Take care to identify the vermilion border of the lip, the eyebrow, or the hairline of the scalp and line up the wound edges appropriately. Handle tissue gently and use skin hooks or fine forceps to prevent wound edge trauma. Close from deep to superficial, placing sutures precisely, and with minimal tension.

Delay the primary closure if there is extensive bacterial contamination, a substantial amount of questionably viable tissue, or the patient is unable to undergo repair at the time of presentation. Delayed primary closure involves direct approximation of wound edges after a period (usually 4–5 days) of wound hygiene with good dressing changes. Delaying closure diminishes the incidence of infection in contaminated wounds if good wound care is provided in the interim.

Secondary closure is when the wound is left open and allowed to heal on its own. Healing depends on epithelization from the wound margins and contraction of the surrounding tissue. Frequent observation is essential as secondary healing can sometimes lead to contracture, a pathologic scar deformity. Secondary closure can yield acceptable results with specific wound types and anatomic sites. Puncture wounds, for example, heal well secondarily while diminishing the likelihood of infection. For both abrasions and puncture wounds, the functional and aesthetic results of secondary closure are generally as good as or better than those obtained by primary or delayed primary closure. Wounds on anatomically concave surfaces (e.g., medial canthal region, perineum) also heal with excellent results.⁶ Secondary healing should also be considered for infected wounds, wounds with significant amounts of devitalized tissue, wounds with foreign bodies, and high-velocity wounds.

Closure by Wound Type

Abrasions

Abrasions are superficial wounds caused by scraping, which involve the epidermis and partial thickness dermis. They frequently heal secondarily within 1–2 weeks. Foreign body fragments can embed in and beneath the skin, and if the interval between injury and debridement exceeds 24–48 hours, the wounds will begin to epithelize and the embedded material will be trapped in the skin, resulting in traumatic tattooing. To avoid traumatic tattooing, sharply debride or scrub the abrasion with a brush. Once the wound is debrided, apply ointment or a semi-occlusive dressing to create a moist wound healing environment to speed re-epithelization. If needed, tape or glue may be used for epidermal approximation to prevent suture mark scars, which could be worse than the actual wound scar.

Puncture Wounds

Puncture wounds are typically left open, treated with wound care, and allowed to heal by secondary intention. Secondary closure reduces the risk of infection and yields a favorable aesthetic result. Grossly contaminated puncture wounds, such as cat bites, are at high risk for infection. These should be copiously irrigated at presentation, and systemic antibiotics are indicated.

Lacerations

The most common wound encountered by surgeons is generally a linear traumatic wound, known as a laceration. Primary closure within 6–8 hours of injury is desirable as it eliminates the need for extensive wound care, allows quick healing, minimizes the risk of infection, and minimizes patient discomfort. For sutured wounds, apply gauze to prevent bacterial contamination, protect the wound, and manage drainage. Dressings are required only for approximately 48 hours, by which time epithelial cells will have sealed the superficial layers of the wound and drainage ceases. Alternatively, apply an antibacterial ointment to minimally draining sutured wounds (see Topical Antimicrobials, below). Ointments maintain a clean and moist wound environment, which promotes healing. Clean wounds can be covered with a semi-occlusive dressing, which allows wound observation and optimizes epithelization, but has limited absorptive capacity.

Complex Wounds

Stellate, degloved, and mutilated tissues are known as complex wounds. Discuss with the patient the difficulties posed by these wounds. These wounds are often treated in the operating room (OR) under general anesthesia because of the extent of injury, need for tissue exploration, removal of foreign bodies, debridement of nonviable tissue, and repair of complex structures. Stellate wounds can be approximated with careful placement of interrupted and three-point sutures. Severely injured tissues may require excision as an ellipse, with closure of the resulting defect.

Degloving refers to circumferential elevation of skin and fat from muscle. The extent of tissue injury is often larger than appreciated. In the acute setting, debride devascularized tissues and observe questionably viable flaps of tissue. The degloved tissue segment may be primarily sewn back into its anatomic location, but avoid closure under tension as an injured but viable flap can quickly convert to ischemic and nonviable when pulled too tight. Consider delayed primary or secondary closure if primary closure leads to ischemia. With extensive degloving, the devitalized tissue may be thinned of subcutaneous fat and replaced as a graft.

Mutilating wounds (e.g., caused by machinery) are often severely contaminated and may involve injury to deeper structures. Prophylactic antibiotic therapy with an agent or combination of agents that offers broad-spectrum coverage is indicated. Repair of underlying bone, muscle, tendon, or nerve may require the operating room. For skin, loose closure should be performed. While tape or staples reduce the risk of infection, suture is often necessary. Avoid excessive amounts as well as multifilament suture, which is more prone to infection.

For complex wounds containing questionably necrotic tissue, foreign bodies, or other debris that cannot be removed sharply, wet-to-dry dressings are effective, simple, and inexpensive. Apply a single layer of coarse wet gauze, allow it to dry over a period of 6–12 hours, then remove. Necrotic tissue, debris, and exudate become incorporated within the gauze and are removed with the dressing. The disadvantages of wet-to-dry dressings are pain and damage to or removal of some viable tissue.

If tendons, arteries, nerves, or bone is exposed, use wet-to-wet dressings to prevent desiccation of these critical structures. Wet-to-wet dressings cause less tissue damage than wet-to-dry dressings but do not produce as much debridement. Most wet-to-wet dressings are kept moist with saline. Use an antibacterial solution (e.g., mafenide, silver sulfadiazine, silver nitrate, povidone iodine, or Dakin's solution containing sodium hypochlorite) on wounds with significant bacterial contamination.

Some wounds are difficult to dress and require special consideration. Do not use compression dressings on flaps or questionably viable tissue because they may cause ischemia. Temporarily immobilize wounds that traverse joints with a plaster splint. For large or irregular wounds, negative-pressure wound therapy (NPWT) is recommended as it conforms well to irregular shapes, removes excess wound fluid, stimulates granulation tissue, improves peripheral blood flow and tissue oxygenation, and reduces wound size.^{7,8} Use caution with NPWT in wounds with exposed blood vessels or bowel. Although NPWT requires expensive dressings and equipment as well as electrical charging, less expensive devices are being tested and surgical providers in poor countries eagerly await disruptive technology with NPWT. NPWT has also been shown to decrease the need for more complex reconstructions, such as in exposed lower extremity fractures.⁹

Crush Injury

Crush injury can result in deep tissue damage leading to compartment syndrome, extremity loss, or death from rhabdomyolysis. Successful treatment depends on early diagnosis. Signs

and symptoms include increasing pain that is out of proportion to stimulus, altered sensation, pain on passive stretching, weakness, tenseness of the compartment, pallor, poikilothermia, and pulselessness.¹⁰ Compartment pressure can be measured, and compartment syndrome is diagnosed if the pressure exceeds 30 mm Hg. Treat by restoring normal blood pressure if hypotensive, remove constrictive dressings or casts, and maintain the limb at heart level. If signs and symptoms persist, perform fasciotomies within 6 hours to prevent irreversible muscle necrosis. Check the serum creatine kinase and, if elevated, stabilize intravascular volume and confirm urine flow to prevent acute renal failure.¹¹ Renal dialysis may be necessary and life saving.

Extravasation Injury

Arterial or venous catheters may become dislodged or the vessel occluded, leading to extravasation of solutions into the interstitial space. Most extravasation injuries heal without complication. For extravasation of a small volume (<150 ml) of a nontoxic agent, manage conservatively with elevation of the limb and careful monitoring. Large-volume (>150 ml), high-osmolar contrast agents, cytotoxic agents, or chemotherapeutic drugs, however, can cause soft tissue necrosis and compartment syndrome. Treatment of these injuries is not standardized; it may include conservative management, hydrocortisone cream, incision and drainage, hyaluronidase injection, aspiration, irrigation, or fasciotomies in the case of elevated compartment pressures.

High-Velocity Wounds

Explosions or gunshots cause extensive tissue damage when the kinetic energy of high-velocity projectiles is released into the soft tissues. Although the entry wound can be small, the exit wound and interspace may contain large areas of ischemic and damaged tissue. Clothing and dirt may also be transmitted into the deep tissues. Radiographs may identify metallic foreign bodies. Identify and extensively debride injured tissue and foreign bodies. Not all fragments will be able to be removed. Leave wounds open to heal by delayed primary or secondary closure.

Bite Wounds

Human bite wounds are usually clenched fist wounds sustained while fighting. Puncture wounds in the metacarpophalangeal joint are at particularly high risk for infection. These “fight bites” are considered infected and must be treated with aggressive irrigation, usually in the operating room, and broad-spectrum antibiotic (e.g., amoxicillin-clavulanate). Obtain radiographs and explore wounds to evaluate for fractures or open joints. Delayed primary or secondary closure is advised due to the high risk of infection. Cat bites or scratches are at high (80%) risk of infection, while dog-bite wounds are at lower (16%) risk for infection, and prophylaxis with amoxicillin-clavulanate is appropriate.¹² Consideration should also be given to rabies treatment (see below). Puncture wounds should be left open and allowed to heal secondarily. Larger lacerations

on cosmetically sensitive areas may be closed loosely with sutures, but patients must be advised regarding the possible risk of infection.

Adjunctive Wound Treatment

Prophylactic Systemic Antibiotics

For most wounds, prolonged antibiotic prophylaxis is not indicated. When it is called for, select an agent based on the bacterial species likely to be present. The anatomic location of a wound may also suggest whether oral flora, fecal flora, or skin flora is likely to be present. Gram staining can provide an early clue to the nature of the contamination. Ultimately, the choice of a prophylactic antibiotic regimen is based on the clinician’s best judgment regarding which agent or combination of agents will cover the pathogens likely to be present. Wound categorization includes clean, clean-contaminated, contaminated, and dirty (Table 36.2).¹³ Risk of infection correlates with wound category. Local factors, such as ischemia, radiation, and foreign body; and systemic factors, such as diabetes, acquired immunodeficiency syndrome (AIDS), and cancer, may increase the risk of wound infection. Prophylactic antibiotics can be considered in the presence of any of these factors. In addition, prophylactic antibiotics should be considered in patients with cardiac valvular disease or a prosthesis.

Topical Antimicrobials

Topical antimicrobials (e.g., antibiotic ointments, iodine preparations, sodium hypochlorite, and silver agents) significantly lower wound infection rates on open wounds and do not appear to impair epithelization in animal models.¹⁴ Antibiotic ointments such as bacitracin, polymyxin, or triple antibiotic ointment (bacitracin, neomycin, and polymyxin B) are useful for abrasions, superficial burns, or along fresh suture lines. Patients may develop allergic dermatitis with prolonged use of these agents. Betadine (10% povidone with 1% free iodine) is an effective antiseptic,

TABLE 36.2

Classification and infection rates of operative wounds

Classification (class)	Infection Rate (%)	Wound Characteristics
Clean (I)	2–5	Atraumatic, uninfected; no entry of GU, GI, or respiratory tract
Clean-contaminated (II)	8–11	Minor breaks in sterile technique; entry of GU, GI, or respiratory tract without significant spillage
Contaminated (III)	15–16	Traumatic wounds <4 hours old; gross spillage from GI tract; entry into infected tissue, bone, urine, or bile
Dirty (IV)	28–40	Traumatic wounds >4 hours old; drainage of abscess; debridement of soft tissue infection

Cruse PJ, Foord R. The epidemiology of wound infection. A 10-year prospective study of 62,939 wounds. *Surgical Clinics of North America*. 1980 Feb;60(1):27–40.

often used for creation of a sterile field, which also promotes angiogenesis and fibroblast proliferation. Dakin's solution (half-strength 0.25% sodium hypochlorite) can be made inexpensively by diluting household bleach, and is useful for grossly infected wounds as well as promoting neodermal thickness and fibroblast proliferation. Silver has microbicidal effects on common wound contaminants and may also be effective against methicillin-resistant *Staphylococcus aureus*. Silver sulfadiazine (Silvadene) has broad antibacterial properties, maintains a moist wound, and has a relatively benign side effect profile (transient leukopenia is occasionally seen). It is useful for partial thickness burns.

Tetanus Prophylaxis

Tetanus is a nervous system disorder caused by *Clostridium tetani* and is characterized by muscle spasm. Wound severity is not correlated with tetanus susceptibility. Therefore, all penetrating wounds, regardless of etiology or severity, are tetanus prone, and a patient's tetanus immunization status must always be considered. Provide post-exposure prophylaxis per guidelines (Table 36.3).¹⁵

Rabies Prophylaxis

Rabies is an acute progressive viral encephalitis. Any mammal can transmit the virus, but carnivores and bats are the only viral reservoirs. Bite wounds in which the animal's saliva penetrates the dermis are the most common route of exposure. Consider vaccination prior to exposure if at high risk. Post-exposure treatment consists of wound care, infiltration of rabies immune globulin into the wound, and vaccine administration. Provide post-exposure prophylaxis per guidelines (Table 36.4).¹⁶ Prior vaccination status determines the vaccination regimen (Table 36.5).¹⁷

TABLE 36.3

Recommendations for tetanus immunization

Tetanus Immunization History	Toxoid	Tetanus Immune Globulin (TIG)
Unknown	Yes	Yes
> 10 years since last booster	Yes	Yes
≥ 5 and ≤ 10 years since last booster	Yes	No
< 5 years since last booster	Yes	No

Note: Administer toxoid and TIG (250 units) with separate syringes at different anatomic sites. Toxoid is contraindicated if there is a history of a neurologic or severe hypersensitivity reaction after a previous dose. Local side effects alone do not preclude use. If a systemic reaction is suspected of representing allergic hypersensitivity, postpone immunization until appropriate skin testing is performed. If a contraindication to a toxoid containing preparation exists, use TIG alone.

*Pediatric diphtheria and tetanus toxoids and acellular pertussis vaccine (DTaP) for patients aged <7 years; tetanus and diphtheria toxoids (Td) if aged 7–10 years; reduced diphtheria toxoid and acellular pertussis vaccine (Tdap) (or Td if Tdap is unavailable) if aged ≥11 and <65 years; and Td for adults aged ≥65 years. Pregnant women should receive Td instead of Tdap, if possible.

Recommendations for Postexposure Interventions to Prevent Infection with Hepatitis B Virus, Hepatitis C Virus, or Human Immunodeficiency Virus, and Tetanus in Persons Wounded During Bombings and Other Mass-Casualty Events. [Image on Internet] 2008. [updated 2008 Aug 1; cited 2014 Jan 29]. Available from: <http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5706a1.htm#top> [public domain]

TABLE 36.4

Rabies: Recommendations for post-exposure prophylaxis based on animal type

Animal Type	Animal Disposition and Evaluation	Patient Prophylaxis*
Dog, cat, ferret	Healthy and available for 10 day observation	Initiate prophylaxis immediately if animal exhibits rabies symptoms+
	Rabid or suspected rabid, no observation is indicated	Initiate prophylaxis immediately+
	Unknown	Consult public health official
Bat, skunk, raccoon, fox, and most other carnivores	Regarded as rabid unless brain laboratory tests are negative	Initiate prophylaxis immediately+
Livestock, horse, rodent, rabbit, hare, and other mammals	Consider each case individually	Consult public health official; rarely requires prophylaxis

*See Table 5 – Rabies: Recommendations for Post-exposure Prophylaxis +If animal is euthanized for brain laboratory testing, stop prophylaxis if tests are negative for rabies.

Animal Type to Postexposure Prophylaxis. [Image on Internet] 2011. [updated 2011 Nov 15; cited 2014 Jan 29.] Available from: <http://www.cdc.gov/rabies/exposure/animals/domestic.html> [public domain]

TABLE 36.5

Rabies: Recommendations for post-exposure prophylaxis

Treatment	Non-immunized Individuals	Previously Immunized Individuals
Wound care	Irrigate and debride the wound; apply a virucidal agent such as povidone-iodine solution.	Irrigate and debride the wound; apply a virucidal agent such as povidone-iodine solution.
Human rabies immune globulin	If possible, infiltrate the full volume (20 IU/kg) around wound(s). If necessary, administer remaining volume IM at another site. Do not use more than recommended dose. Use separate syringes and anatomic sites from vaccine.	Do not administer.
Human diploid cell vaccine or purified chick embryo cell vaccine	1.0 ml IM on days 0, 3, 7, and 14*	1.0 ml IM on days 0 and 3*

*Administer in deltoid for adults; anterolateral thigh may be used for children. To avoid sciatic nerve injury and reduce adipose depot delivery, the gluteus is not used.

Rabies Vaccines and Immunoglobulin Available in the United States. [Image on Internet]. 2011. [updated 2011 Apr 22; cited 2014 Jan 29]. Available from: http://www.cdc.gov/rabies/medical_care/index.html [publicdomain]

Postoperative Wound Care

Keep closed wounds clean and dressed for 24–48 hours after repair. Assess wounds at risk for infection within 48 hours of care. Teach the patient to look for signs of infection (e.g., spreading erythema, purulent drainage, and fever). After 48 hours, gentle cleansing with running water removes bacteria and crusting. Patients should not place tension on the wound or engage in strenuous activity in the first 6 weeks, while collagen deposition and tensile strength of the wound increases rapidly. After this period, tensile strength increases more slowly, eventually reaching a maximum of 80%–90% of normal skin strength.

The timing of suture or staple removal is a balance between optimal cosmesis and the need for wound support. On one hand, sutures should be removed early, before inflammation and epithelialization of suture tracts occurs, usually by 7 days. But it takes a number of weeks for the wound to gain significant tensile strength, and early suture removal can result in dehiscence. Early suture removal is warranted for some wounds, particularly those in aesthetically sensitive areas under minimal tension. Facial sutures may be removed on day 4 or 5. Sutures in wounds subject to greater stress (e.g., wounds on the extremities or trunk) should remain in place longer (2–3 weeks), as should sutures in wounds sustained by patients who have impeded wound healing.

After suture removal, numerous methods are employed to minimize unsightly scar formation. The aesthetic outcome of a scar is largely determined by the nature and severity of the wound, which are outside the surgeon's control. The greatest impact a surgeon can have is by providing meticulous care when the acute wound is initially encountered. Postoperatively, massage, silicone bandages, pressure garments, and the application of lotion and sunblock may optimize outcomes. Nevertheless, the healing wound is fragile, and topical application of ointments to achieve an improved scar appearance may actually achieve the opposite result. Vitamin E, which is commonly applied to healing wounds, can induce contact dermatitis and cause scars to look worse.¹⁸

Chronic Wound Care and Impaired Wound Healing

A number of local and systemic factors can interfere with wound healing. Local factors include tension, infection, ischemia, hematoma, seroma, trauma, edema, and irradiation. Systemic factors include hypothermia, tobacco, malnutrition, diabetes mellitus, and drugs (corticosteroids or chemotherapy). Evaluate for these factors and take appropriate measures to improve the chances for optimal healing when possible.

Tension may lead to separation of wound edges. Causes of tension include absent tissues, inherent skin elasticity, poor surgical technique, movement of joints, or inadequate wound support. Minimize tension by undermining the wound edges during closure to allow easy coaptation. Limit surgical ellipses from wound edges to as narrow as possible and along relaxed skin tension lines. After suture removal, support the wound using tapes (e.g., Steri-Strips) for 3–6 weeks. Consider splinting wounds over joints. Tissues with dermal edges that do not bleed are

ischemic. Monitor questionably viable tissue and debride when declared nonviable. Maintain intravascular volume and tissue perfusion with fluid or blood and provide supplemental oxygen if necessary. Rough handling of tissue edges with forceps causes additional iatrogenic injury. Avoid crushing the epidermis by handling wound edges gently at the dermal level with toothed forceps or fine skin hooks.

Hematomas and seromas increase the risk of wound dehiscence. Ensure hemostasis at the time of wound closure and correct bleeding diatheses. Close wounds over a drain if there is a large dead space, with significant risk for hematoma or seroma formation. Evacuate large hematomas or seromas before they solidify. Small hematomas or seromas can usually be observed as they often resorb. Edema results from the accumulation of fluid in the interstitial space. It may occur as an acute process due to inflammation or as a chronic process due to venous insufficiency, lymphatic insufficiency, or low plasma oncotic pressure. Edema inhibits healing. Clearing edema improves healing and may be accomplished by elevation, compression therapy, or NPWT.

Radiation irreversibly damages tissues and can cause wounds to heal slowly, or healed wounds to break down. Irradiated tissue is characterized by a thickened and fibrotic dermis, a thin epidermis, pigment changes, telangiectasia, decreased hair, and increased dryness. Wounds within irradiated beds may require tissue transfer for healing. Vitamin A supplementation can lessen the adverse effects of radiation on wound healing.¹⁹

Hypothermia impairs wound healing, increases the infection rate, and slows wound tensile strength. Prevent or correct hypothermia with systemic and local tissue warming to maximize wound healing potential. Supplemental oxygen benefits wound healing. Reduce the incidence of wound infection by improving the F_{iO_2} with supplemental oxygen. Restore or improve the circulating volume by administering crystalloids or blood.

Tobacco smoking reduces tissue oxygen concentrations, impairs wound healing, and contributes to wound infection and dehiscence. Encourage acutely injured patients to stop smoking. Noninjured patients scheduled to undergo surgery should stop smoking at least 3–4 weeks before making an elective surgical wound.

Edema results from fluid accumulating in the interstitial space. It may occur as an acute process with trauma or as a chronic process due to venous insufficiency, lymphatic insufficiency, and a low plasma oncotic pressure. Edema raises tissue pressure, forms a fibrinous clot, and inhibits perfusion and healing. Clearing the edema is necessary and may be accomplished with compression or NPWT.^{7,20}

Good nutritional balance and adequate caloric intake (including sufficient amounts of protein, carbohydrates, fatty acids, vitamins, and other nutrients) are necessary for normal wound healing. Protein is particularly important as it provides an essential supply of the amino acids used in collagen synthesis, and protein replacement and supplementation improves wound healing. Vitamin C deficiency causes scurvy, marked by failed healing of new wounds and dehiscence of old wounds. When low, supplement Vitamin C (100–1,000 g/day) to improve wound healing.²¹ Vitamin K is necessary for blood clot formation and hemostasis, the first step in wound healing. Vitamin D is required for normal calcium metabolism and therefore plays a necessary role in bone healing. Dietary minerals (e.g., zinc and iron) are also essential for normal healing. Zinc replacement and supplementation can

improve wound healing, but daily intake should not exceed 40 mg of elemental zinc.²¹

Diabetes mellitus is associated with poor wound healing and an increased risk of infection. Monitor and control blood sugar levels. Diabetic patients, with decreased acral sensation, must also closely monitor themselves for wounds and provide meticulous wound care. Many drugs impair wound healing. Corticosteroids, for example, inhibit all aspects of healing. In the setting of an acute wound that fails to heal, patients requiring corticosteroids may reduce the dose, administer topical or systemic vitamin A

(25,000 IU/day orally),²² and in extreme situations, supplement with anabolic steroids to restore steroid-retarded inflammation. Chemotherapeutic agents both hinder tumor growth and impair wound healing. Acutely wounded patients who have recently been treated with, are currently taking, or will soon begin to take chemotherapeutic agents, must be closely observed for poor healing and complications. Vitamin E (α-tocopherol) impairs collagen formation and causes inflammation. Despite its popularity, topical application can cause contact dermatitis and worsen the appearance of the scar.¹⁸

AQ1

COMMENTARY

Ntakiyiruta Georges

This topic is excellently and comprehensively discussed in the chapter. I would like to add that one should consider performing an early diversion of stools for any perineal wound (from a gunshot wound (GSW), burn, or other cause), since persistent stool contamination will impair wound healing and any wound closure attempt (delayed primary closure or skin graft) will fail.

Another aspect of wound care is the management of wounds as a result of necrotizing fasciitis and Fournier's gangrene, both of which are highly prevalent in Rwanda. Both are life-threatening soft-tissue infections that are characterized by rapidly spreading inflammation and necrosis of the skin, subcutaneous fat, and fascia. The management of them involves good resuscitation measures, aggressive wound debridement, high doses of intravenous antibiotics, and regular relooks in the operating room. Delays in surgical treatment are associated with high mortality. Surgical debridement will result in an extensive wound. Wound healing takes a long period of time, and wound closure usually requires skin grafting.

Another aspect of chronic wound to highlight is chronic leg ulcers, also known as tropical ulcers. Tropical ulcers usually require antibiotics for up to 4 months and wound care. When there is good granulation tissue, the wound can be skin grafted. Tropical ulcers that have lasted for many years can undergo malignant changes.

Venous ulcers are also challenging, although leg elevation and leg compression with elastic bandages may help. Sclerotherapy of the varicose vein or varicose vein stripping are very useful in the management of nonhealing varicose veins.

The management of pressure sores in bedridden paraplegic patients is very difficult. The management principles for chronic wound are the same, but the most challenging in resource-poor setting is the prevention of pressure sores in high-risk patients.

Okao Patrick

Wound care is one of the pillars of surgical care. This chapter discusses the major aspects of wound care and clarifies many contentious topics. Good medical history and clinical

examinations should be emphasized as part of the overall wound care. The cost of wound care can be markedly reduced if early and proper wound debridement and dressing is done because it will eventually allow early closure.

Okechukwu O. Onumaegbu

The goal of wound care remains a healed wound with the best outcomes in form and function. Adequate preparation of the wound without prejudice to the advanced trauma life support (ATLS) protocol is essential for this outcome. The use of regional anesthetic blocks outside the zone of injury is beneficial in freeing up the anesthetist (often in short supply) to attend to other pressing patient care. Where there is no anesthetist, this skill enables the surgeon to adequately, in dual role, attend to the surgical care of the traumatic wounds presenting.

Wound irrigation and debridement: Bulb syringes are not commonly available, but 20 ml syringes serve a similar purpose, albeit with less ease. With a number of patients presenting with wounds that have been treated with unconventional methods, assessment of these late presenting or chronic wounds may be preceded by serial dressing sessions using a "wet-and-dry" approach. An example of this approach is a wet/saline-wrung gauze inner layer overlaid with dry meshed gauze and cotton wool padding; this allows for moistening of the adherent agents on the wound floor and debridement of same. This allows for ambulatory initial management of these patients. The benefit is glaring in situations where bed space for inpatient care is a concern. Materials that have been found applied to wounds range from the identifiable and obliterating or desiccating like gentian violet, powdered contents of antibiotic capsules, and so on, to the unidentifiable and unimaginable. Wet-to-dry dressings changed every 6–12 hours are very effective but not usually feasible in our locality because of the manpower limitations for the required nursing care and the limited supplies from the central sterile supplies unit or, more often, its usually smaller equivalent.

Human bite wounds are more commonly on free-border facial structures like the lips, ala of the nose, and the pinna. They do not usually result from the incidental "fight bites" to the knuckles but from a deliberate attempt by a subdued

opponent to inflict aesthetically relevant damage to his assailant. These structures usually present in such situations with full-thickness defects. Repair and reconstruction of these may be undertaken primarily by careful sharp excision of the often ragged edges. When contamination is deemed gross or indeterminable, a delayed primary approach is advised. Careful attention to the anatomic landmarks such as the white roll of the vermillion border of the lip may be enhanced by tattooing the relevant points with surgical ink using the tip of a small-caliber (23-gauge/25-gauge) hypodermic needle before local anesthetic infiltration and debridement. Additional excision of otherwise unaffected tissue may be necessary to obtain a better aesthetic result. For instance, crescentic excisions may be required lateral to the alae of the nose to facilitate apposition of a central upper lip defect without tension. In a not-so-related setting, a ray amputation may be required to improve the functional outcome in a low transproximal phalangeal traumatic amputation of the ring or middle finger, where replantation is precluded.

Brushing abrasions under saline or clean water irrigation, or with the added bubbling effect of dilute hydrogen peroxide solution irrigation on the wound, helps to prevent traumatic tattooing. Disposable brushes, however, are often a luxury, as are resterilizable brushes. The concept of resterilization is discouraged for fear of disease transmission. Sterile meshed gauze used as a brush will just as efficiently remove any ingrained dirt.

Degloving injuries are best laid back into position preferably over a wet single layer of gauze as they are often not clean wounds. Except for very lax elderly skin (which however, has its own blood supply concerns) suturing the “flap” back into position is almost invariably going to be under tension.

Chronic wounds will almost always yield bacterial growth on culture of wound swabs. Antibiotic treatment should not be undertaken merely on account of a positive culture with demonstrated sensitivities. The clinical state of the wound and any associated systemic effects should guide the commencement of antibiotic therapy. The swab result may then guide the choice of antibiotic employed.

A word on leg ulcers in sickle-cell disease patients: Aggressive surgical skin cover either with local flaps or split skin grafts is often ill-advised, as these ulcers are notorious

for recurrence. Adequate bed rest and judicious wound care with medication support (antimalarial prophylaxis, vitamin C in large doses of up to 1,000 mg daily, folic acid, and good hydration) are conservative approaches that yield remarkable healing in these ulcers.

Sterman Toussaint

Wound care is often one of the most challenging tasks for surgeons; it is critical for non-immediate life-threatening patients and sometimes for trauma patients. This chapter outlines a practical approach to wound care and pays particular attention to the initial aspects of wound management. This is very helpful for surgeons because, most of the time, the outcome of the healing process for any wound is tributary on the initial management.

It is also interesting in this chapter that the priority is not on the availability of unlimited resources and technology, but rather on the surgeon’s basic and appropriate knowledge of wound management. However, it gives the surgeon the capacity to use the latest technological inventions, so any surgeon or surgery resident could use this as a good companion in the footpaths of daily wound management.

For coordinating ZL/PIH surgical activities in Haiti, where our network is concentrated in the countryside, the management of wounds is particularly more challenging because most of the time our patients have tried some empiric unadapted treatment before showing up to the hospital. We often have to deal with wounds that were initially dressed with a spider’s web, horse or cow feces, or soil; in most of these cases, the patient was not vaccinated for tetanus.

It is also good to find that this chapter highlights the importance of the surgeon’s experience in some cases, especially regarding the use of prophylactic antibiotics. However, some procedures, like skin graft and flaps, should be emphasized because neglected or complex wounds often need these procedures to heal.

Finally, since the sixteenth century when Ambroise Pare wrote *La Maniere de Traiter les Plaies* (The way to treat wounds), wound care has advanced, but initial wound management, especially cleaning the wound with soap and water, has remained the key to successful wound care.

Author Queries

Page 427: AQ1: AU: OK to add?

Page 428: AQ2: AU: Please review changes made for clarity.