Complications of wounds and cosmetic surgery although frequent can be accurately managed with a combination of timely surgical and medical intervention to ensure the best possible outcome. The lack of soft tissue protection and a large quantity of susceptible synovial, tendon, ligament, and neurovascular structures make early and meticulous evaluation of limb wounds critical. Chronic wounds should be considered infected and may become afflicted with sarcoid, Pythium spp, Habronema spp, or Draschia spp, and rarely neoplasia. Methicillin-resistant Staphylococcus aureus (MRSA) infections can consequently be difficult to treat and are associated with increased morbidity, mortality, and treatment costs. Skin grafting is usually used following a period of open wound management and after healthy granulation tissue formation. Penetrating wounds of the abdomen or thorax have a guarded prognosis resulting from the ensuing potential for infection and pneumothorax. Gunshot wounds limited to the skeletal muscles have a good prognosis, whereas injuries that involve vital organs decrease survivability.

COMPLICATIONS OF REPAIR

Osseous Sequestration

The distal limbs of horses are extremely susceptible to damage of the periosteum and underlying bone because of the lack of soft tissue protection. Because the periosteum provides the blood supply to the outer one third of the cortical bone, disruption of the periosteum leads to ischemia of the bone with eventual bone death secondary to these alterations in blood flow. This ischemic locale is very susceptible to bacterial colonization and proliferation originating from the inciting trauma. Blunt trauma with no external entry wound may result in sequestrum formation indicating that bacterial
inoculation may also occur by way of the bloodstream. This type of injury is more commonly present with trauma to the metacarpal or metatarsal bones.\textsuperscript{1}

The body may be able to resorb the sequestrum or expel it from the draining tract depending on the size of the devitalized bone fragment. Larger fragments usually persist and lead to more extensive clinical disease. The sequestrum can become a chronic nidus thereby delaying the healing process. Because of the lack of vascularization, the immune response at the site is inadequate, leading to a chronic infection that persists in the face of a normal immune system.\textsuperscript{2,3} The lack of a relative reliable blood flow impedes the migration of osteoclasts to the site hindering the natural resorption of bone. These two events collectively result in a chronic inflammatory focus that the body cannot or only slowly resolves.\textsuperscript{1}

The most common sites for sequestrum formation are those with a relative lack of soft tissue covering, such as the phalanges, metacarpal or metatarsal bones, calcaneous, distal radius, medial tibia, and skull (Fig. 1). The affected site most commonly involves some degree of soft tissue swelling and usually has a coexisting draining fistulous tract. There is usually not a significant lameness, but some deep palpation over the sequestered bone generally produces a painful response.\textsuperscript{1,4}

Sequestra formation may not be readily noticeable on survey radiographs until 3 to 4 weeks after the inciting injury has occurred.\textsuperscript{5,6} Correct radiographic orientation and contrast radiography may be useful to the location and extent of a sequestrum. Ultrasound evaluation may also benefit in further localizing a fistulous tract and bone fragment.\textsuperscript{7} The chronic fistulous tract is identified as an anechoic fluid or gas-filled tract surrounded by an echogenic fibrous scar tissue. The sequestrum is identified as a highly echogenic bone fragment surrounded by an anechoic pocket of fluid.

Complete resection and removal of the fistulous tract, involucrum, and sequestrum is best performed with the horse under general anesthesia. Preoperative bacterial

\begin{figure}
\centering
\includegraphics[width=0.5\textwidth]{image}
\caption{Sequestrum formation on the distal aspect of the third metacarpus in a chronic wound that is healing by third intention. There is relative lack of soft tissue covering in this area, which predisposes the underlying bone to more trauma. Disruption of the periosteum leads to ischemia of the bone with eventual bone death secondary to these alterations in blood flow.}
\end{figure}
culture of the tract or the sequestrum itself is not considered essential because surgical removal of all necrotic debris is the procedure of choice. The tract should be dissected carefully from the adjacent soft tissue until the sequestrum is reached. All nonviable debris and bone should be removed. The surrounding bone should be curetted until the underlying healthy bone bleeds. Excessive bony proliferation may be removed with an osteotome or chisel to contour the bone. Excessive contouring of long bones may result in the development of fissure lines in the cortex that could lead to significant fracture of the bone when the horse is recovering from anesthesia. Healthy adjacent periosteum should be preserved if possible to minimize excessive bone remodeling. If a clean and complete resection of the involucrum and the surrounding necrotic debris adjacent to the involucrum is achieved, primary closure of the skin defect is preferred. With sequestra involving the distal limbs, it is important to be conservative in the amount of tissue removed. If complete resection of the contaminated tract is not possible, open drainage and second-intention healing signify the best choice.1

A nonadherent permeable or semiocclusive dressing to keep the bone moist and allow for granulation tissue formation should be applied to wounds left to heal by second-intention healing. A protective bandage is applied over this primary covering and changed as often as needed based on the quantity of the exudate. Skin grafts may be used to speed healing in large wounds once the defect has filled in with granulation tissue. This is especially important in wounds of the dorsal third metacarpal or metatarsal bone.

Most horses that develop sequestra have a good prognosis once the local infected nidus is removed. Return to full function after complete resolution of clinical signs is possible in most cases. Secondary trauma to the soft tissue, tendon, or bone sustained during the initial injury is the most likely factor leading to permanent problems in those horses that do not return to full function.2

Exposed Bone

Exposed or denuded bone is a common complication of wounds of the distal aspect of the limb.8 Exposed cortical bone in which the periosteum has been removed is prone to desiccation of the superficial layers of the cortex, which may result in infectious superficial osteitis and sequestrum formation.9 Exposed bone within a wound can delay wound healing directly if the bone becomes infected, or indirectly because its rigid structure can delay the formation of granulation tissue and wound contraction.10

Distal limb avulsion wounds with exposed bone increase in wound size for 14 to 21 days. Wound expansion predominantly is caused by the distraction forces applied across the wound during the inflammatory and debridement stages of wound healing, and the lack of a granulation tissue bed in the center of the wound to neutralize the tensile forces exerted on the wound margins from the surrounding skin. Wounds with a small amount of exposed bone, or wounds without exposed bone, expand for a shorter period because less time is required for granulation tissue to seal the wound. Larger wounds with exposed bone take longer to form a granulation bed and subsequently wound contraction is postponed.10

Periosteal insults from blunt trauma, tendon or joint capsule strain, surgical manipulation, or laceration or degloving injuries may result in extensive periosteal exostosis.11–13 Injuries involving bones in horses stimulate more periosteal new bone growth than similar wounds in other species and ponies.11,12 More extensive periosteal reaction in young compared with adult horses has been attributed to a more active osteoblastic activity of the periosteum in young horses.13 The extensive periosteal new bone growth seen in adult horses is poorly understood. Deferred collagen lysis
compared with other species may be a contributing factor.\textsuperscript{11} The more extensive periosteal new bone formation in horses compared with ponies is alleged to be the result of a slower onset and longer duration of the periosteal response and prolonged extensive limb swelling in horses, as compared with ponies.\textsuperscript{12}

Despite the common occurrence of exposed bone associated with trauma to the distal aspect of the limb, there has been little investigation into methods of stimulating coverage of granulation tissue over exposed bone in horses. Granulation tissue development is a very important role in second-intention healing because it provides a barrier to infection and mechanical trauma for the underlying tissues. Healthy granulation tissue is resistant to infection and provides a moist surface for epithelialization. The delay in wound healing caused by exposed bone has prompted the search for different methods to promote granulation tissue coverage of bone in other species.

Head trauma, thermal injury, and surgical oncology often results in exposed bone of the cranium in humans.\textsuperscript{9,14} In these cases the outer cortex of the uncovered portion of the cranium is fenestrated with drill holes, burrs, or lasers to expose the medullary cavity from which granulation tissue grows to cover the exposed bone.\textsuperscript{9,15–17} Similarly, exposed cortices of long bones in humans have been fenestrated with drill holes to promote granulation tissue formation.\textsuperscript{12} It has been suggested that the drill holes promote healing by allowing osteogenic factors from the medullary cavity access to the wound, or by the enhancement of healing of bone and soft tissue by a nonspecific response known as “the regional acceleratory phenomenon.”\textsuperscript{18} Cortical fenestration combined with drugs that promote topical granulation tissue may accelerate granulation tissue coverage compared with control wounds, but further investigation is needed.

Cortical fenestration of 1.6-mm drill holes in the cortex of the second metacarpal bone in experimentally created wounds in dogs resulted in clot formation over the bone that promoted granulation tissue formation and may have protected the bone’s outer layers from desiccation.\textsuperscript{19} The effects of cortical fenestration with 3.2-mm drill holes were evaluated in experimentally created wounds of the distal aspect of the limb of horses.\textsuperscript{20} Cortical fenestrated wounds became covered with granulation tissue earlier than control wounds, and fenestration had no significant effect on sequestrum formation. The granulation tissue growing directly from the bone surface also contributed to granulation tissue formation (Fig. 2). If the wounds are not large (<6 × 6 cm) it may be difficult to realize a significant contribution from the granulation tissue growing from the cortical fenestration sites alone. Cortical fenestration may also be advantageous if it is used with other methods of promoting granulation tissue.\textsuperscript{20} Splinting of the limb is usually not necessary for the recovery from general anesthesia unless there are associated traumatic injuries to the limb that suggest instability.

\textbf{Degloving Injuries}

Degloving or avulsion injuries are not uncommon in equine practice, and their management can be challenging because of prolonged treatment, cost, and sometimes unknown outcome.\textsuperscript{20–22} The body that becomes entrapped in hazards or a limb that becomes intertwined in fencing can quickly sustain tissue damage. The most common sites for this type of trauma are the hemithorax, dorsal aspect of the metacarpus or metatarsus, and the cranial aspect of the tarsus.\textsuperscript{22} Vascular, soft tissue, and bone damage is directly proportional to the length of time and effort the horse uses to free itself. Some injuries that seem to be superficial and innocuous on the surface may involve vital structures surrounding the wound or later develop cutaneous and internal abscesses or ulcerative cellulitis. Local wound care should be an integral part of the initial treatment.\textsuperscript{23} Severity and duration and location of the laceration determines
the best approach to the treatment of degloving injuries because healing of wounds involving the distal limb is often delayed when compared with other areas of the body, further complicating the healing process.

Primary repair of the wound is the preferred treatment for wounds that involve detachment of skin with maintenance of an intact blood supply (Fig. 3). Complications, such as sequestrum formation, are lessened and healing is improved when the exposed bone and tendons are covered with skin and soft tissue in the immediate posttrauma period. Closing as much of the wound as possible improves the cosmetic and functional outcome and lessens the amount of healing having to occur by second intention.

Delayed closure of a degloving injury is preferred when there is significant contamination, swelling, and trauma of the wound without loss of skin. Initial treatment for the first 2 to 3 days after injury includes debridement and lavage of the wound followed by wet to dry bandages to facilitate further debridement. Pressure bandaging is indicated to remove edema associated with the injury. Debridement of the wound edges and appropriately applied tension sutures facilitate closure of the wound because skin retraction is a complication of delayed closure.

Second-intention healing is indicated for degloving injuries in which there is a considerable loss of skin immediately at the time of injury or in which a closed degloving
injury has developed avascular necrosis of the skin with subsequent sloughage. The wound is sharply debrided until only healthy tissue remains. A hydrogel Carradress dressing (Carrington, Irving, Texas) is applied to the region of the wound that remains open. These dressings are able to contribute moisture to dehydrated tissue, augment autolytic debridement, and absorb some moisture from an exudating wound. The dressing is applied to the wound bed followed by application of a conformable absorptive dressing (Kerlix, Kendall, Mansfield, Massachusetts). A firm cotton bandage is used to provide warmth and support and to minimize excessive movement of the

Fig. 3. (A) Degloving injury to the right hemithorax secondary to a laceration with a metal post. There is extensive undermining of the skin along the dorsal and ventral caudal aspects of the wound. (B) Primary repair of laceration. Debridement of the wound edges, walking sutures, and appropriately applied tension sutures facilitate closure. (C) The laceration repair dehisced 6 days after primary repair. The wound is debrided, cleansed, and honey is applied topically to facilitate third-intention wound healing. (D) A secondary topical pad and reusable body meshing is used to facilitate wound cleansing. (E) Laceration 25 days after initial injury. Contraction, epithelialization, and granulation tissue formation is progressing well.
limb and associated wound area. Depending on the size and location of the wound, skin grafting may be indicated to facilitate complete healing. Grafting should be delayed to permit maximum wound contraction, which depending on the location and size of the wound may be 4 to 8 weeks after injury.

Dorsal knuckling of the fetlock and an inability to extend the digit is a common complication of distal limb wounds that is usually associated with the loss of the extensor tendon of the distal limb.24 Supporting the dorsal aspect of the limb to counteract the pull of the flexor tendons on the palmar or plantar aspect of the limb is the premise for management of extensor tendon disruption. The wound and extensor tendon laceration is managed by second-intention healing without suturing the extensor tendon.22,25 A rigid polyvinyl chloride splint is applied to the dorsal or palmar or plantar aspect of the distal limb after wound bandaging. The bandage and splint, which maintains the limb in extension and prevents dorsal knuckling of the fetlock, are retained until normal limb function returns, which may vary from 7 days to 6 weeks.1

Wound Infection and Dehiscence

Wound infection and dehiscence occur in both surgically or trauma-induced wounds. Tissue integrity and perfusion, wound repair processes, and bacterial challenge and host responses heavily influence infection. A very important determinant of wound infection is the bacterial inoculation dose. An inoculum size of $10^5$ organisms per gram of tissue is a bacterial challenge below which soft tissue wounds may heal without infection. Samples from infected wounds should be taken on a sterile swab from deep within the infected site or tract after cleansing of the wound with dilute povidone-iodine or chlorhexidine scrub, followed by a thorough lavage with sterile isotonic fluid or by harvesting fresh exudate on a sterile swab. Debridement of wounds should be performed on cleaned wounds before the administration of systemic antimicrobials. Necrotic, devitalized, or macerated tissue and organic debris should be removed. Copious lavage should be performed with dilute solutions, such as 0.1% povidone-iodine or 0.05% chlorhexidine solution, which maintain antiseptic properties and minimize tissue toxicity. Pressures of greater than 8 psi and up to 70 psi dislodge adherent bacteria without forcing them deeper into tissue. A 60-mL syringe with a 14-gauge needle can generate 8 psi and a Water Pik (Water Pik, Fort Collins, Colorado) can generate up to 70 psi.

There is no replacement for a representative culture and sensitivity of a wound. It is helpful, however, to have an idea of the organism to expect when faced with a need for therapy in the absence of culture results. Common isolates from equine wounds include *Streptococcus* spp most predominately followed by coagulase-positive and coagulase-negative *Staphylococcus* spp in addition to Enterobacteriaceae, *Pseudomonas* spp, and anaerobes. Gentamicin and penicillin or cephalothin is a good treatment choice. Aminoglycosides have a concentration-dependent bactericidal action and a good concentration-dependent postantibiotic affect that remains for several hours after the dose is administered and bacteria continue to take up the drug through a combination of passive and oxygen-dependent facilitated processes. Antimicrobial susceptibility of *Pseudomonas* spp is unpredictable and therapy should be based on culture and sensitivity. Local wound care with silver sulfadiazine is effective in most confirmed pseudomonas skin infections. Systemic antibiotics are generally administered for 7 to 10 days in combination with local wound debridement and care.21

Regional Limb Perfusion

Regional intravenous infusion achieves high concentrations of antibiotic by diffusion from the vascular space into the traumatized and infected synovial membranes.
Survival rates of horses treated with systemically injected antibiotics in conjunction with regional intravenous antibiotic infusion is greatly increased. Higher concentrations of antibiotic are detected sooner in joints after regional intravenous compared with regional intraosseous antibiotic infusion.

To perform standing regional intravenous perfusion, the horse is sedated. A high four-point block is performed using mepivacaine when the synovial structure to be treated is located at or below the fetlock. Anesthesia of the ulnar and median nerves, or tibial and peroneal nerves, is performed when the area to be treated is located at the level of the carpal or tarsal joints, respectively.

An Esmarch’s bandage or a pneumatic tourniquet is applied proximal to the affected synovial structure to occlude the venous system. Usually, the bandage or tourniquet is applied to the mid-metacarpus or metatarsus, but in cases of infection of the carpal or tarsal structures, the bandage or the tourniquet is applied to the distal aspect of the radius or the mid tibial region. The Esmarch’s bandage is maintained in place after antibiotic infusion for a period of 30 to 40 minutes and then released.

The antibiotic, generally an aminoglycoside or cephalosporin (amikacin, 1 g diluted in 20–30 mL of saline solution; gentamicin, 1 g diluted in 20–30 mL of saline solution; cefotaxim (Claforan), 1–2 g diluted in 20–30 mL of sterile water) is injected into one of the local superficial veins when the Esmarch’s bandage is in place. The palmar-plantar medial and lateral veins are used when the infusion is performed at the level of the fetlock. The cephalic and saphenous veins are used when the tissues intended to be perfused are localized at the levels of the carpal and the tarsal joints. The skin over the vein is surgically prepared using an antiseptic technique. The vein is catheterized using a 22-gauge, 2.5-cm catheter with an infusion plug. A 23-gauge butterfly catheter with an incorporated extension set also works well for this purpose.

The volume of infusion varies between 20 and 30 mL, but smaller volumes can be used for treating foals. Different recommendations for the rate of infusion are reported. The rate of infusion can be as fast as 60 mL/min or 2 mL/min for a total delivery time of 30 minutes for a 30-mL volume. For standing treatment, a fast rate of administration is more convenient and seems to offer satisfactory results. Once the catheter is withdrawn several gauze sponges are applied over the venipuncture site and the site is wrapped with an elastic bandage to avoid a hematoma formation.

**Foreign Bodies**

Most horses with foreign bodies present with a nonhealing persistent draining tract. This wound is recognized only after prolonged medical treatments have been unsuccessful in resolving a local infection. Most foreign bodies are not evident radiographically unless, however, a gas line is evident secondary to a bacterial infection. Plastic and wood have the same radiodensity as soft tissue and are not visible radiographically. Ultrasound, contrast radiographs, or probing the wound with a surgical instrument may aid in the identification of these foreign bodies.

**Thermal Injuries**

Burns are uncommon in horses, with most resulting from barn fires (Fig. 4). Thermal injuries may also result from contact with hot solutions; electrocution; lightning strike; friction as in rope burns; abrasions; radiation therapy; and chemicals, such as improperly used topical drugs or maliciously applied caustic agents.

Most burns are superficial, easily managed, inexpensive to treat, and heal in a short time. Serious burns, however, have serious complications that can result in rapid, severe burn shock or hypovolemia with associated cardiovascular changes. Smoke inhalation and corneal ulceration also are of great concern. Management of severe
and extensive burns is difficult, expensive, and time consuming. The large surface area of the burn dramatically increases the potential for loss of fluids, electrolytes, and calories. Burns covering up to 50% or more of the body are usually fatal, although the depth of the burn also influences mortality. Massive wound infection is almost impossible to prevent because of the difficulty of maintaining a sterile wound environment. Long-term care is required to prevent continued trauma, because burn wounds are often pruritic and self-mutilation is common. Burned horses are frequently disfigured, preventing them from returning to full function. Before treatment, the patient must be carefully examined, with particular attention paid to cardiovascular function, pulmonary status, ocular lesions, and the extent and severity of the burns.26,28–30

Although specific guidelines do not exist for burns of horses, euthanasia should be recommended for deep partial-thickness to full-thickness burns involving 30% to 50% of the total body surface area.29,30 The availability of adequate treatment facilities, cost of treatment, and pain experienced by the horse during long-term care should be considered when deciding treatment. Euthanasia is often an acceptable alternative because convalescence may take up to 2 years.31 Cost of treatment and prognosis should be thoroughly discussed with the owner.26,27,32,33

**Excessive Skin Tension**

Skin sutured with excessive tension is likely to have complications of healing because of local ischemia with pressure necrosis of the surrounding skin and the pull through of sutures at the skin edge with subsequent wound disruption. Undermining the surrounding skin, relief incisions, and appropriately applied tension sutures are the most common methods that can be used to lessen tension along the skin margins.

The surrounding skin can be undermined up to 4 cm from the wound edge without associated complications.1,34 Relief incisions can be closed after the primary incision is closed or left to heal by second intention.
To not interrupt the blood supply to the primary suture line, tension sutures are positioned well away from the wound margin. Once the tension suture is in place, the primary incision line is sutured to close the wound edges. Tension suture patterns include vertical mattress, horizontal mattress, far-far-near-near, and far-near-near-far patterns. Vertical mattress sutures with or without skin support to prevent laceration of the wound edges, such as polyethylene or rubber tubing, are useful in reducing tension on the primary suture line. This tension suture support method is used in areas that cannot be bandaged well, such as the upper limb, body, and neck region. It is contraindicated to use tension suture supports under a limb cast or heavy bandage because these supports may cause tissue necrosis and suture line failure. Tension sutures are not effective after 7 to 10 days and should be removed in a staggered fashion with one half removed initially followed by the remaining sutures later.1

Nerve Damage

Nerve damage or transection of a nerve in the limb or trunk is not readily recognized at the initial time of the injury. Many lower limb lacerations in the pastern, fetlock, and heel bulb areas with significant injury almost certainly have concurrent transection of the palmar or plantar digital nerve that is not recognized during the examination of the injury. Unilateral transection of the palmar or plantar nerves associated with a traumatic laceration seems to regrow after transection to reinnervate the affected area and cause minimal clinical problems in horses.4

Neuroma formation after nerve transection, although rare, can occur and may cause lameness, together with focal pain directly over the wound and nerve site. The lameness improves after local anesthetic is placed at the site of the neuroma. Surgical removal of the neuroma and associated nerve is the treatment of choice to which most horses respond favorably.

Potential sites for wound-associated nerve transection other than the limb include the lateral aspect of the proximal radius and elbow where the radial nerve lies fairly superficial and the shoulder region in which lacerations and blunt trauma may contribute to suprascapular nerve injury (Fig. 5). Nerve injury to either location, however, is uncommon.

Injuries to smaller nerve branches most likely occur with all types of traumatic wounds but seem to have minimal impact on wound healing. Occasionally, focal areas of wounds may be hypersensitive to touch and other stimuli, which may indicate previous damage to nerve branches and potential small neuroma formation. This hypersensitivity tends to resolve as the wound is covered with healthy granulation tissue.1

Major Blood Vessels

Pastern lacerations are the most common location for wounds to involve a major blood vessel, such as the palmar digital vein or artery. Significant blood loss can occur if the hemorrhage is not controlled soon after injury by temporarily clamping the vessel or applying pressure over the wound with a bandage in the standing horse (Fig. 6). Anastomosis of the vessels is usually not possible because the severed ends usually retract into the wound. Large vessel lacerations, which may involve the saphenous vein along the medial aspect of the tarsus, the cephalic vein along the medial aspect of the distal radius, and the greater metatarsal artery along the lateral aspect of the metatarsus, are best treated by ligation of the severed ends if they can be identified. Fortunately, collateral circulation usually develops readily.1
Fig. 5. Sweeney of the left shoulder. Prominence of the scapular spine is present secondary to atrophy of the suprascapular musculature resulting from blunt trauma of the suprascapular nerve.

Fig. 6. Laceration of the palmar axial surface of the right fore limb. Temporarily clamping the palmar digital artery or vein or applying pressure over the wound with a bandage in the standing horse can avert significant blood loss. The severed vessels are usually severely damaged, which prevents anastomosis. Collateral circulation of the affected vessels develops rapidly in 2 to 4 weeks.
Movement

The extent of movement of the skin relative to the underlying bed of granulation tissue is usually much higher in the limb regions than in the trunk. This is possibly exacerbated by the relative lack of skin elasticity and the obvious proximity of the limb skin to structures with a high degree of motion, such as joints and tendons. Trunk wounds have a better available reparative blood supply than those of the distal limb.

An injury to the distal limb metacarpal or metatarsal region of a horse that involves the flexor tendons or their sheaths requires healing by the ingress of blood vessels from adjacent structures. As healing attempts to progress, however, repeated tendon contraction and limb movement moves the injury away from the site of the skin wound leaving the damaged tissues with no effective mechanism for healing.

Rigid limb casting of a distal limb wound is very effective in facilitating wound contraction and epithelialization if the tissues are initially sharply debrided and lavaged (Fig. 7). The mechanisms for this may be more complex than merely controlling movement. Although movement of the limb and wound is limited, added surrounding pressure applied to the wound may also facilitate the healing process. Warmth, restriction of movement, and the presence of a moist healing environment in conjunction with a cast are probably significant factors that contribute to wound healing. Which aspects of the exudate are desirable and enhancing of wound healing and which are inhibitory is not known in the horse. Heat, pain, swelling, or lameness created by the cast indicate attentive re-evaluation of the wound and the consideration of cast removal or cast change.1

Fig. 7. Laceration of the left hind plantar pastern region. (A) Initial debridement of the wound and lavage of affected synovial structures. (B) Rigid limb casting is very effective in promoting wound contraction and epithelialization. Warmth, restriction of movement, and the presence of a moist healing environment in conjunction with a cast are significant factors that contribute to wound healing. Heat, pain, swelling, or lameness created by the cast indicate attentive re-evaluation of the wound and the consideration of cast removal or cast change.
Self-Mutilation

Significant self-mutilation of wounds through rubbing, biting, and pawing can occur if the horse is not adequately restrained or medicated. Usually, the most intense pruritic episodes occur in the first weeks of wound healing during the inflammatory phase of repair and during eschar sloughing but can be a later complication associated with burn wounds.\textsuperscript{27,35} To prevent extreme self-mutilation, the horse should be cross tied or sedated at this time and use of a neck collar may be considered. Delayed healing, poor epithelialization, and complications of second-intention healing may limit return of the animal to their previous use.

Exuberant Granulation Tissue

Surgical resection is a simple and effective method to control exuberant granulation tissue. The procedure is performed with the horse standing, because granulation tissue is not innervated. Strips of granulation tissue can be shaved from the wound bed in a distal to proximal direction to produce a flat surface level with or slightly (approximately 2 mm) below the surrounding wound edges. The epithelial margin should be preserved to allow continued healing. A pressure bandage is usually necessary to control hemorrhage after excision. In lower limb wounds of horses this technique has been successful in enhancing second-intention healing that was delayed because of protruding granulation tissue. This technique is preferred for the removal of exuberant granulation tissue over other methods, such as application of caustic drugs, because it is easy to perform; provides tissue for histologic evaluation, if needed; and preserves the epithelial margin for continued healing. As with any alternate technique, healing by contraction and epithelialization must subsequently be supported by maintaining the limb in a firm support bandage and limiting excessive motion of the wound or excessive granulation recurs. Corticosteroids may be applied topically to curb the early formation of exuberant granulation tissue, hence facilitating epithelialization and wound repair. The ability of some corticosteroids to suppress the formation of exuberant granulation tissue in the early phases of healing may be related to their ability selectively to decrease the release of profibrotic transforming growth factor-\(\beta\) from monocytes and macrophages, inhibiting lysosomal activity and fibroblastic proliferation. Corticosteroids are generally applied at the earliest signs of formation of exuberant granulation tissue with one or two applications being all that is needed to achieve the desired effect. Continued applications are not recommended, because this may exert negative effects on wound contraction, epithelialization, and angiogenesis. Corticosteroids should not be applied to an infected wound because they inhibit the inflammatory response required to eliminate microorganisms.

Application of a cast to a lower limb wound is indicated in cases in which it is difficult to control exuberant granulation tissue. Wounds over joints or tendons may require immobilization because continued movement disrupts healing. Frequently, the hock or carpus is involved in these types of compound injuries. When the limb is mechanically stable, the wound should be bandaged for a few days before applying a cast, to allow superior wound debridement and permit dissipation of edema, which ensures a better-fitting cast. Casts minimize the formation of exuberant granulation tissue by reducing motion. Casts should be maintained no longer than necessary over lower limb wounds for reasons similar to those mentioned for bandages and to minimize the development of cast sores. Generally, casts over wounds should be changed every 3 to 10 days, but this depends on the nature and location of the wound and the temperament of the horse. Skin grafts can be used after cast removal to facilitate wound coverage. A splint bandage is continued during this period.
COMPLICATIONS OF CONTAMINATED WOUNDS

Methicillin-Resistant Staphylococcus Aureus Infection

There have been increasing reports of MRSA infection and colonization in horses and other domestic animals. MRSA is resistant to all β-lactam antimicrobials and frequently to a wide range of additional antimicrobial classes because of the presence of an altered penicillin-binding protein. Infections can consequently be difficult to treat and are associated with increased morbidity, mortality, and treatment costs, compared with infections caused by methicillin-susceptible S aureus strains.

Identification of MRSA infection and colonization in horses in veterinary hospitals and in the community, and reports of transmission of MRSA between humans and animals, have raised concern about the role of animals in MRSA infection in humans and the potential for animals to become a reservoir of MRSA. In one recent veterinary hospital study the incidence rate of nosocomial MRSA infection was at the rate of 1.8 per 1000 admissions, with an incidence density of 0.88 per 1000 patient days. Administrations of ceftiofur or aminoglycosides during hospitalization were the two risk factors associated with nosocomial MRSA colonization. In another veterinary hospital study horses that had received at least 72 hours of penicillin treatment had a 5.8-times higher chance (odds) of harboring penicillin-resistant staphylococci than horses that were not admitted to the clinic and did not receive penicillin treatment. Control horses with a 72-hour stay at the clinic but no penicillin treatment still had a 2.4-times higher chance (odds) of harboring penicillin-resistant strains. This work demonstrated that horses entering the hospital harbor staphylococci-containing antibiotic-resistance genes. Shortly after hospitalization, horses acquired a specific multidrug-resistant skin flora that was presumably selected for and maintained in the hospital by the use of penicillin. These authors proposed that antibiotics should be limited to the treatment of infection and not used for infection prevention and that such prudent use could help prevent selection for multidrug-resistant strains, such as MRSA strains in animals.

MRSA infections are generally classified as hospital or community acquired and as superficial colonization of a wound without signs of infection, superficial soft tissue infection or cellulitis, complex skin and skin-structure infection, or osteomyelitis. Superficial wounds may be treated without the use of oral or IV antibiotics. Regular cleansing of the wound with 4% chlorhexidine gluconate and soft tissue debridement is effective at reducing the colony-forming bacteria load. Topical application of honey or silver-coated dressings has been shown to be effective. Careful monitoring of the wound is imperative to ensure adequate response to treatment.

Ventral midline celiotomy closures are prone to MRSA infection (Fig. 8). Clinical signs usually present 5 to 10 days after surgery with a purulent exudate escaping from the subcutaneous tissue. Opening of the skin closure accompanied by local superficial debridement with the application of 4% chlorhexidine, topical honey, or silver-coated dressings has been an effective treatment. Although intranasal mupirocin can prevent endogenous acquired MRSA infections in an ICU and is effective in overall decolonizing of nasal carriers, mupirocin is less effective in decolonizing extranasal sites, such as wounds. Doxycycline in combination with rifampin has been shown to have a synergistic activity against MRSA activity in people.

Local antimicrobial treatment, consisting of implantation of vancomycin-impregnated polymethyl methacrylate beads, has also been performed to increase the concentration of antimicrobials in the local environment and decrease adverse systemic
Vancomycin has been documented to elute from polymethyl methacrylate in vitro. The vancomycin-impregnated polymethyl methacrylate beads are changed frequently, because there is concern that daily wound lavage increases the elution rate of vancomycin from the polymethyl methacrylate and reduces the local vancomycin concentration by dilution.

**Abdominal Wounds**

Most injuries that involve the abdominal wall are best treated with wound exploration, abdominocentesis, ultrasound, and rectal examination to document whether a wound breaches the peritoneal cavity. Injuries to the deep inguinal area are especially prone to penetrating injuries of the abdominal wall. Septic peritonitis and potential bowel eventration are serious complications if left unattended. Most injuries penetrating the abdominal cavities are best treated with the horse under general anesthesia to permit thorough wound exploration, debridement, abdominal lavage, and primary closure.

Large wounds that involve an open abdominal cavity are emergency conditions. Emergency first aid treatment usually requires immediate closure of the wound to prevent bowel from exiting the wound. Provisionally bandaging, suturing, or clamping the wound until exploration and repair of the wound can be used. With severe abdominal contamination abdominal drainage using large-bore catheters egressing the ventral abdomen should be performed for repeated abdominal lavage of the abdomen for several days after surgery. Large abdominal wall defects that cannot be closed primarily at surgery should be bandaged and left to heal by second intention. Many of these defects close completely. Abdominal wall herniation is usually secondary sequelae. A synthetic mesh implant may also be used to facilitate closure 2 to 3 months after injury.

**Thoracic Wounds**

Injuries of the chest are common and rarely result in penetrating the thorax, and are usually the result of the horse running over or into a fixed natural object, such as tree, fence post, or other substantial stationary object. These wounds should be thoroughly explored for the presence of foreign bodies or secondary rib fractures. Intercostal perineural local anesthesia facilitates a more thorough exploration and assists in the control of pain that often accompanies these injuries.
Fig. 9. Deep inguinal injury of the LH limb. (A) Multiple deep lacerations and contusions to the medial thigh and abdominal wall. (B) Prolapse of small intestine 2 days postinjury through the initial wound. Thorough wound exploration, debridement, abdominal lavage, and primary closure of the wound was done immediately after injury under general anesthesia.

Fig. 10. Egressing lavage fluid from an abdominal lavage catheter. A penetrating abdominal wall injury was left undetected for 12 days postinjury. A large-bore catheter exiting the ventral abdomen should be inserted for repeated abdominal lavage of the abdomen for several days after surgery.
debridement and lavage should be performed, followed by removal of rib fragments, foreign bodies, and other debris that may be present within the depths of the wound. It is imperative that the wound be closed primarily or covered with an airtight dressing and left to heal by second intention. Primary muscle flaps of the longissimus and external abdominal oblique muscles, diaphragmatic advancement flaps, or prosthetic meshes can be used to facilitate closure of the wound over the lateral thorax.52,56 General anesthesia may be used if pneumothorax is not present; however, it is not recommended because of further undefined respiratory and cardiovascular risks.1

Horses with large axillary wounds should be closely observed for the development of subcutaneous emphysema and impending pneumothorax, however, which may develop secondarily to axillary wounds that do not initially penetrate the chest (Fig. 11). The wounds of this area often expand deep into the axilla along the thoracic wall and tend to aspirate air into the wound and deeper structures.56 To inhibit air from moving into the tissues the wound may be packed with sterile gauze and the skin over the defect temporarily closed using stent bandages. The packing should be removed every 24 to 48 hours and the wound repacked until healthy granulation tissue has developed to occlude the defect. To reduce the potential for subcutaneous emphysema the horse should be confined to a stall or cross tied to minimize movement of the limb.1

Emergency triage is necessary in some cases when pneumothorax is the result of interruption to the thoracic wall. If there is any evidence of respiratory distress, including flaring of the nostrils or short rapid breaths, the wound should be covered with an airtight dressing (saran wrap) to prevent further incursion of air into the thorax.

Pneumothorax may be detected by ultrasound, thoracocentesis, and radiography. Diagnostic thoracocentesis may be performed by placing a 3.5-teat cannula or 14-gauge catheter high into the thirteenth intercostal space adjacent to the caudal margin of the rib into the thoracic cavity and attaching a fluid extension line with sterile fluid (2–3 mL). If the fluid foams out of the extension, pneumothorax is confirmed; if the fluid is aspirated into the thoracic cavity it is not likely that pneumothorax is present. If pneumothorax is present a three-way stop cock is attached to the extension line and then to a 60-mL syringe or active suction pump. The air is removed by active suction

Fig. 11. Deep ventral chest and axillary wound. This wound went into the axilla along the thoracic wall penetrating the chest. To inhibit air from moving into the tissues the wound was sharply debrided, packed with sterile gauze and the skin was temporarily closed. This procedure was performed with the horse standing to avoid complications of pneumothorax with general anesthesia. The packing was changed every 48 hours until healthy granulation tissue developed to occlude the defect.
with precautions to prevent the introduction of more air through the original wound (Fig. 12). Radiography is useful to determine if air is present within the thoracic cavity and reveal the presence of a collapsed lung, secondary rib fractures, or foreign bodies. In horses experiencing severe respiratory distress intranasal oxygen may be beneficial.

Horses with acute and especially chronic chest wounds should be closely evaluated for secondary pleuritis by means of radiography, ultrasound, and fluid analysis obtained by thoracocentesis. Pleuritis secondary to thoracic trauma is uncommon if the thoracic wounds are suitably treated. The caveat is that penetration of the thoracic cavity may not be readily apparent and accurate treatment with broad-spectrum antibiotics and surgical debridement of the wound is delayed. Thoracoscopy is indicated to identify associated injuries and foreign bodies in horses with severe or complicating injuries.¹

**Gun Shot**

Traumatic wounds caused by acts of violence are an increasingly important cause of injuries to horses.⁵⁷,⁵⁸ Wounds limited to the skeletal muscles have a good prognosis, whereas injuries that involve vital organs decreased survivability. Ten horses with injuries caused by gunshots or stab wounds by spears or knives were treated. The depths of many soft tissue injuries were initially underestimated. Seven of 10 horses survived requiring surgical and medical treatments.⁵⁸ In another study 22 horses were evaluated for injuries caused by firearms. Most had been shot with 0.22-caliber rimfire cartridge bullets or lead shotgun pellets, although other weapons included BB pellets, a 0.35-caliber rimfire cartridge bullet, and airgun pellets. In eight of these horses the injury was confined to the skin or skeletal muscles, seven of which returned to their previous use. In 14 horses, additional injuries included the sinus, pharynx, mandible, tooth, aorta, eye, tibia, gastrointestinal tract, joint, and trachea. Of the 11 horses with injuries to deep or vital structures other than the eye, three died, five were euthanatized, and three survived.⁵⁷

Debridement of the wound and delayed primary closure 4 to 5 days after injury are the preferred treatment for gunshot injuries. Treatment by minimal debridement, lavage, and the establishment of drainage allows for excellent results when only skin and skeletal muscle were involved. The benefit of using antimicrobial agents remains equivocal, but may be indicated if the wound is heavily contaminated or vital

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**Fig. 12.** Thoracoscopy tube placed in the left thirteenth intercostal space. This horse developed pneumothorax secondary to a right thoracic injury. Air was removed by active suction with precautions to prevent the introduction of more air through the original wound.
structures are in close proximity to the site of injury. Small-caliber ammunition may have sufficient velocity to enter the abdomen, respiratory tract, or skull. In such situations more aggressive treatment aimed at repairing damaged vital structures may be indicated.57

**Pythiosis**

Infections in horses caused by *Pythium insidiosum* are most commonly restricted to the cutaneous and subcutaneous tissues in horses that have prolonged contact in lakes, ponds, and swampy areas.59–61 There may be single or multiple nonhealing, rapidly enlarging, tumor-like, ulcerative, nodular masses with multiple draining tracts and serosanguineous discharge.60 These lesions are usually on the limbs and ventral abdomen but can occur anywhere on the body including tendons, ligaments, and bone in chronic cases (Fig. 13). The lesions are usually intensely pruritic and horses may mutilate the wounds if not closely monitored.60,61 There may be mild to marked lymphadenopathy. Skin lesions often contain “kunkers,” yellowish gritty coral-like bodies ranging from 0.5 to 1.5 cm in diameter. Kunkers are composed of necrotic eosinophils, *Pythium* sp hyphae, and necrotic vessels.60,61 Cutaneous pythiosis, although seemingly straightforward, is often misdiagnosed as cutaneous habronemiasis, sarcoids, or excessive granulation tissue, which are characterized by similar gross lesions.60–62

Because of possible recurrence, it has been recommended that surgical excision be followed by systemic administration of antifungal drugs.60,61 Antifungal therapy may not be effective, however, because of the lack of ergosterol (the target molecule of antifungal drugs) in the plasma membranes of oomycetes. This probably explains why antifungal chemotherapy alone has shown very little success in treating phycomycosis.62 Topical application of “Phycofixer” consisting of ketoconazole, rifampin, dimethyl sulfoxide, and hydrochloride (University of Florida, Gainesville, and Franck’s

![Fig. 13. Pythiosis present within the RF fetlock region. The lesion was markedly pruritic resulting in the horse mutilating the lesion. Pythiosis is often misdiagnosed as cutaneous habronemiasis, sarcoids, or excessive granulation tissue, which is characterized by similar gross lesions.](image-url)
Compounding Pharmacy, Ocala, Florida) beneath an absorbent bandage has met with good success in wounds that cannot be surgically debrided. Recently, immunotherapy using a newly formulated vaccine has been successful in treating cutaneous pythiosis in horses and dogs. This vaccine has been shown to be effective for both acute and chronic cutaneous pythiosis in the horse.

For most phycomycosis infections the prognosis is guarded to poor regardless of the advances in treatment. The reason is that many horses have multiple bone lesions at the time of initial presentation. The rate of recurrence after attempted surgical excision has also been a major factor in the failure of treatment.

**Myiasis**

Chronic open wounds can become contaminated with habronemiasis, a common cause of ulcerative cutaneous granulomas in horses. Habronemiasis is a result of infection with larvae of the nematodes *Habronema muscae*, *Habronema majus*, and *Draschia megastoma*. Infection of a wound with these larvae induces proliferative, exuberant granulation tissue caused by a presumptive hypersensitive reaction to dead or dying larvae. Lesions of chronic wounds are most commonly seen on the limbs and any area of traumatized skin.

The onset of habronemiasis is often characterized by the rapid growth of papules or failure of a wound to heal with the development of exuberant granulation tissue. Lesions may be solitary or multiple and are characterized by ulceration, exudation, intermittent hemorrhage, exuberant granulation, and pruritus (Fig. 14). Wounds often contain small yellow granules commonly called “sulfur granules” representing necrotic, caseous, or calcified material surrounding nematode larvae.

The disease is most common during the spring and summer when fly populations are active, and lesions often regress during the winter. The diagnosis is often made exclusively on the basis of history, compatible clinical signs, the location of lesions, and the presence

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**Fig. 14.** Chronic wound of RF fetlock contaminated with *Habronema* spp larva. The two large lesions are characterized by ulceration, exudation, intermittent hemorrhage, and exuberant granulation tissue. Small yellow granules (sulfur granules) are present in the wound representing necrotic, caseous, or calcified material surrounding nematode larvae.
of yellowish granules. Biopsy is the method of choice for confirming the diagnosis, which reveals nodular to diffuse eosinophilic dermatitis. Multiple foci of coagulative necrosis with or without degenerating nematode larvae in the center are characteristic of this disease. Habronemiasis must be differentiated from proliferative granulation tissue, sarcoids, pythiosis, squamous cell carcinoma, and other neoplasms.

A combination of local and systemic treatment aimed at reducing the size of the lesions, reducing associated inflammation, and preventing reinfestation is most effective. Massive lesions and wounds refractory to medical treatment may be removed surgically or at least debulked before topical and systemic treatment. Corticosteroids are used to reduce inflammatory hypersensitivity reactions, and for smaller lesions, topical or intralesional application is favored. Topical preparations that contain anti-inflammatory, larvicidal, antimicrobial, penetrating, and protective ingredients are commonly used. Ivermectin has been reported to be effective in the treatment of habronemiasis in horses, because it kills infective larvae and adult worms in the stomach.

COMPLICATIONS OF NEOPLASIA

**Squamous Cell Carcinoma**

A variety of tumors have been reported in association with chronic wounds. Neoplasia secondary to trauma or thermal injury is not uncommon in humans, and can develop acutely but more often latently, several years after the injury. Squamous cell carcinoma has a prevalence rate of almost 2% in human burn wounds. Although scar malignancy in animals is less frequently diagnosed than in humans, various causes, including chronic irritation, as in the case of the chemicals applied to a wound, may potentially lead to development of squamous cell carcinoma. Squamous cell carcinoma and fibrosarcoma have been identified in association with scars resulting from burns in the horse (Fig. 15). Squamous cell carcinoma has been associated with cutaneous scars in a llama and a horse. Other complications include habronemiasis, keloid-like fibroblastic proliferations, sarcoids, and other burn-induced neoplasia.

The clinical management of squamous cell carcinoma can include surgical excision, cryosurgery, electrosurgery, intralesional chemotherapy with such agents as cisplatin or 5-fluorouracil cream, immunotherapy, hyperthermia, and radiotherapy. Cryotherapy controls squamous cell carcinoma of the skin but is not optimal for recurrent...
squamous cell carcinoma or larger tumors. Intralesional injection with cisplatin in oil or topical or intralesional administration of 5-fluorouracil is effective. Hypertrophic scars, which commonly develop following deep second-degree burns, generally remodel in a cosmetic manner without surgery within 1 to 2 years. Because scarred skin is hairless and often depigmented, solar exposure should be limited. Chronic non-healing areas should be excised and autografted to prevent neoplastic transformation. Return of squamous cell carcinoma associated with incomplete removal of the lesion is not uncommon, which subsequently requires chronic retreatment.

Interstitial brachytherapy with iridium-192 sources has several advantages compared with other possible treatments. Although management is intensive and more costly than other treatments, it is very effective in eliminating the lesion and causes little tissue defect. Delayed healing, poor epithelialization, and complications of second-intention healing may limit return of the animal to previous uses.

**Sarcoid**

Sarcoid is a benign tumor of fibrous tissue of horses, donkeys, and mules. Sarcoids are the most frequently diagnosed tumor in horses, with sarcoid transformation an increasingly important cause of wound healing failure. Surveys have estimated the prevalence of sarcoid at 20% of all equine neoplasms and 36% of all skin tumors.

Sarcoids are presumably caused by bovine papilloma virus type 1 and 2 infection, although retrovirus etiologies have been suggested. The mode of virus transmission and presence of latent infections are not clearly understood. Peripheral blood mononuclear cells may serve as host cells for bovine papilloma virus type 1 and 2 DNA and contribute to virus latency. Sarcoi ds are recognized as having six different clinical manifestations (occult, verrucose, nodular, fibroblastic, mixed, and malignant-malevolent) and can occur at any cutaneous site. These lesions are characterized by proliferation of neoplastic fibroblasts and thickening or ulceration of the skin.

Horses with sarcoids at other sites seem to be particularly prone to sarcoid transformation, as are those that have close contact with other horses having sarcoids. Transformation is also more likely in uncovered wounds in summer months when flies are abundant. Body, trunk, or facial wounds that contain sarcoid cells usually develop verrucose sarcoids, whereas limb wounds develop fibroblastic sarcoids that are easily confused with exuberant granulation tissue. Some wounds partially heal, whereas others fail to heal at all even if the overall extent of sarcoid involvement is small. Wounds on horses with sarcoids at other sites should be treated particularly carefully, with attention not to cross-contaminate the wounds, no matter how small and insignificant the wound.

Fibroblastic sarcoids strongly resemble exuberant granulation tissue or staphylococcal pyogranuloma, especially when it progresses at the site of a wound, and especially in limb wounds. Traumatic skin injuries that fail to heal may contain considerable sarcoid components in the wound margins, and the sarcoid tissues can be interdispersed with granulation tissue. Sporadic infiltration of sarcoid tissue at a granulation wound site is very difficult to identify and can be easily missed on biopsy. Careful deep biopsy and a skilled pathologist are essential. The presence of sarcoid transformation in a wound site adds critically to the therapeutic challenges. Early diagnosis and treatment is the most effective course for resolution because most sarcoids involving wounds are prone to getting worse with time and develop into larger more invasive lesions.

Surgically debulking a wound with sarcoid tissue is the most effective treatment for lesions involving wounds. Surgical removal is complicated by the regrowth of the sarcoid at the surgical site and complications of complete wound healing because of lack
of a suitable means for wound closure or the subsequent interference with normal function. The rate of regrowth of the equine sarcoid following surgical excision is closely dependent on the extent of the tumor and the degree to which the surgeon can define its limits. Small, well-defined tumors carry the best prognosis for surgical removal, whereas extensive areas of poorly defined verrucose and mixed sarcoid may result in rapid regrowth of a more aggressive sarcoid type. The earliest regrowth of sarcoids occurs within days of incomplete excision and is usually accompanied by rapid wound dehiscence and subsequent failure to heal.\textsuperscript{83} Viral latency may be one explanation for the high rate of recurrence following surgical excision of sarcoids. In one study bovine papillomaviral DNA was detected in essentially all sarcoids examined. There seems to be a regional variation in the prevalence of viral types with sarcoid tumors. Viral DNA in normal skin samples from horses with sarcoids suggests the possibility of a latent viral phase.\textsuperscript{84}

Cryotherapy and immune-mediated therapy have mixed results when used to eliminate sarcoid tissue in wounds. Cryotherapy is generally used as an adjunct therapy after surgical debulking of the wound and in areas where complete excision of the sarcoid is not possible. Repeat treatments are often needed and complicate the healing of the wound. Poor cosmesis related to regrowth of white hair and scarring is one of the most common "cosmetic" complications associated with cryotherapy.

Radiation therapy using interstitial brachytherapy with iridium-192 sources has been used for the treatment of equine sarcoids affecting the eyelid, lower limb, and joints with good results of greater than 90\% efficacy (Fig. 16). These procedures are relatively simple to use when the clinician and radiation oncologist can work as a team to maximize the efficacy of the treatment. Although expensive and management intensive, more clients are willing to pay the expense to achieve the excellent results associated with this approach.\textsuperscript{4}

![Fig. 16. (A) Fibroblastic sarcoid present on the axial surface of the right forelimb. The sarcoid developed secondarily from a wound to the same area. Other sarcoids were previously present on the body. (B) The wound was surgically debrided and interstitial brachytherapy with iridium-192 in plastic straws was applied within the wound.](image-url)
COMPLICATIONS OF SKIN GRAFTS

Skin grafting decreases healing time and is one of the best techniques for covering a wound that has been chronically affected by exuberant granulation tissue. Skin grafting of lower limb wounds should be considered to cover the granulating wound bed if contraction has ceased and the wound bed is large.8,85 Frequently, however, wounds in horses are treated for several weeks before skin grafting is initiated. At this point granulation tissue is mature, fibrous, and has less of a blood supply than newly formed granulation tissue. Other complications of graft acceptance and healing are wound infection and sequestra formation.

Chronic inflammation, inherently present during second-intention healing of wounds on the distal portion of limbs of horses, may be at least as important as infection because it reduces the quality of the granulation bed and results in the production of a moderate amount of purulent exudate, both of which negatively influence acceptance of grafts.12 As a result, the ability of a wound bed to accept a graft is lessened. It is imperative that chronic granulating wounds be debrided to a level below the skin surface down to a level of healthy granulation tissue before graft application.8,86–88 To increase the success of graft acceptance wound bacteria must be minimized. β-Hemolytic *Streptococcus* spp, *Proteus* spp, and *Pseudomonas* spp are capable of producing destructive proteolytic enzymes and excessive purulent discharge that breakdown fibrinous attachments between the graft and recipient bed.89,90 Topical antiseptics have better efficacy than antibiotics in reducing bacterial wound load because the latter increase the risk of patient sensitization and the development of resistant organisms especially when used routinely over prolonged periods in uninfected wounds.88,90 Infected wounds, however, should be treated with broad-spectrum antibiotics while awaiting culture results. The bone underlying the wound should be radiographed for evidence of sequestra and excessive pericortical dystrophic mineralization. Large wounds often develop healthy granulating tissue around the perimeter before a sequestrum completely defines itself.

Donor site is influenced by the method of grafting, color and texture of the donor hair, cosmesis of the donor site, and ease of obtaining skin. Common sites for obtaining donor skin include pectoral, dorsal neck region, perineum, ventral midline, ventral lateral abdomen, and sternal region caudal to the girth area.8,91

**Pinch Grafts**

Pinch grafts are distinct pieces of skin (3 mm in diameter) produced by excising an elevated cone of skin. Graft acceptance is as high as 75% using pinch grafts partially because of the fact that the pockets of granulation tissue hold the graft in contact with the wound. Complications include necrosis of the graft, slower wound healing, improper orientation of hair, and thin skin coverage of the wound.

Necrotic spots along the top of the granulation pockets normally occur during healing, after which the graft epithelializes circumferentially. Because pinch grafts are small, complete epithelialization of the wound often takes more than 70 days.91 Improper orientation of hair growth is a complication of pinch graft application despite repeated efforts properly to align the hair to match that of the recipient area. A cobblestone appearance with thin subcutaneous tissue is sequelae of pinch graft applications that may not be cosmetically acceptable for show horses.

**Punch Grafts**

Punch grafts are circular pieces of skin that are directly removed from the locally anesthetized donor site or by obtaining biopsies from an excised piece of donor skin.
Common complications of punch graft failure are incomplete removal of the underlying subcutaneous tissue from the graft, recipient site hemorrhage, and motion.

Because punch grafts are full thickness they must have the subcutaneous tissue and fascia removed from the dermis with a surgical blade before implanting, because these layers prevent revascularization and subsequent graft failure. Placing grafts in saline-soaked sponge gauze for a short period of time minimizes graft desiccation while recipient beds are created. Accumulation of blood and serum beneath the graft displaces the grafts from the recipient site. Hemorrhage can be avoided by ensuring that it is controlled before grafting. Displacement of the grafts can also be minimized by using a biopsy punch a size smaller than used to obtain donor graft to ensure a snug fit in the recipient bed. Displacement of the graft by motion can be minimized by securing the wound under a heavy bandage (Fig. 17). Displacement of grafted tissue at wrap changes can be reduced by soaking the primary bandage before removal. Casting is not indicated for punch graft techniques because punch grafts are not indicated for grafting over moveable areas of the body.

**Tunnel Grafts**

Tunnel grafts are useful for healing of wounds that are hard to immobilize or bandage as on the dorsal surface of the hock or fetlock. Graft survival rates of 80% have been reported with excellent cosmetic results. Complications of tunnel grafting include the placement of tunnel grafts too close to one another, failure of the graft to become exposed, and accidental removal of the tunnel graft when removing the overlying granulation tissue.

This technique requires harvesting of full-thickness or split-thickness strips of skin 2 to 5 mm wide and slightly longer than the length of the wound’s edges. These grafts are placed in granulation tissue that has been allowed to develop 4 to 8 mm above skin level. These tunnels can be created using a cutting needle, flattened K-wire with a trocar point, or malleable alligator forceps. The graft is then tunneled approximately 6 mm below the surface of the granulation tissue at the recipient site ensuring that the

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**Fig. 17.** Punch biopsy grafts in place on the dorsum of the fetlock. Several grafts failed to take because of hemorrhage, displacing grafts at wrap changes, and movement at the grafting site.
epidermal side of the graft faces the surface of the wound. Tunnel grafts should not be placed closer than 2 cm apart to prevent excessive necrosis of granulation tissue. The cut ends of the skin strips are sutured to the skin on either side of the granulation bed. A tourniquet may be useful to control hemorrhage and improve visualization of the strips for procedures that involve grafting on a limb. If placed the correct depth, the granulation tissue overlying the graft should slough in 7 to 10 days. If this does not occur, it should be excised at this time. Adjacent granulation tissue that is raised should be excised at this time. Most tunnel graft failures are attributable to accidental removal of the graft during removal of the overlying granulation tissue or failure of the graft to become exposed. Exposure of the graft if necessary may be facilitated by placing malleable probes or wires through the tunnels to cut through the overlying granulation tissue.

FULL-THICKNESS SHEET GRAFT

Full-thickness or split-thickness grafts can be applied as a sheet or expanded before transplantation. The full-thickness sheet graft is the most cosmetic type of free sheet graft because it contains all the properties of the surrounding skin, provides maximum piliation, and can withstand pressure and friction. Full-thickness grafts are not as readily accepted because there are less exposed blood vessels available for imbibition of plasma and for inosculation (Fig. 18).

No specialized equipment is needed for harvesting, and the procedure can often be performed in the standing sedated horse using local anesthesia. Donor sites of full-thickness grafts should be sutured. The graft should be cut slightly larger than the recipient bed to allow for shrinkage after the graft is excised because of recoil of elastic fibers in the deep dermal layers of the graft. The full-thickness graft should be sutured to the donor site with some tension to prevent occlusion of the dermal vessels that may occur if the graft is allowed fully to contract.

Fig. 18. An unmeshed full-thickness sheet graft on the dorsal surface of the fetlock. Full-thickness sheet grafts often require more nourishment than can be supplied by the granulating recipient wound. As a result, full-thickness grafts are usually reserved for fresh uncontaminated wounds.
A high oxygen gradient between the wound and the graft is essential for neovascularization of the graft and graft acceptance. Full-thickness grafts treated with hyperbaric oxygen therapy developed less granulation tissue, edema, and neovascularization, but more inflammation. The superficial portion of these full-thickness grafts was also less viable than the superficial portion of those not treated with hyperbaric oxygen therapy.94

Full-thickness sheet grafts are often considered compromised because they often require more nourishment than can be supplied by the granulating recipient wound. As a result, full-thickness grafts are usually reserved for fresh uncontaminated wounds. The upper layers of a full-thickness graft are more likely to slough because full-thickness grafts require more nourishment and have fewer exposed vessels for this purpose. Because of the lack of abundant donor skin in the horse, the graft often must be meshed and expanded to achieve coverage of the wound larger than the donor area.

**Split-Thickness Grafts**

Split-thickness grafts are more readily accepted than full-thickness grafts, and may be used to cover granulation beds that are less than ideal.95 Because blood vessels branch as they become more superficial in the dermis, more vessels are cut and exposed with split-thickness grafts. The greater the number of exposed vessels the better the absorption of nutrients is from the granulation bed. A split-thickness sheet graft is more cosmetic than a pinch or punch graft because the thickness of the graft and orientation of the hair are uniform and coverage by the graft is more complete.

A mechanical dermatome or a free-hand knife (Watson Skin Graft Knife, Down's Surgical, Sheffield, England) is used to split the dermis. The latter is preferred because it is easy and economical to use. General anesthesia is necessary to obtain the graft; split-thickness donor sites are very painful to the horse, because many nerve endings are exposed. Grafts less than 0.5-mm thickness in the horse lack strength, durability, and have sparse or no hair follicles or exocrine glands, which results in less sebaceous secretion. Grafts harvested between 0.63 and 0.75 mm have good coverage of hair and greater durability than do thinner grafts.96,97 Unlike full-thickness grafts, suturing of the donor site is not required and primary graft contraction is minimal because a portion of the dermis remains intact and heals with a scarred appearance.97

The grafts can be applied to the wound after the horse has recovered from general anesthesia. This reduces anesthesia time and the possibility of damage to the graft during the recovery process. The graft can then be affixed to the wound with the horse standing without using local anesthesia by overlapping and gluing the graft with cyanoacrylate to the skin surrounding the wound. To increase graft success in an area that is difficult to immobilize, such as the fetlock or hock, the graft can be further secured by suturing the graft to its recipient bed with simple interrupted absorbable sutures (Fig. 19). Meshing grafts greatly enhances graft acceptance by preventing mechanical disruption of the graft from its vascular supply by exudate. Fenestration of the graft also enables topically applied antimicrobial agents to contact the graft bed and allow for the escape of fluid produced by the wound.95,97

Although proper graft bed preparation and grafting techniques are important for successful graft application, successful graft acceptance depends greatly on attention to postoperative care. During the initial 4 to 10 days the graft may become edematous and pale. These changes are from a loss of blood supply caused by vessel constriction and the expulsion of erythrocytes while the graft is nourished by passive imbibing nutrients onto its open vessels from the granulating bed by way of plasmatic imbibition. By day 10 the graft typically has a complete union to the graft bed. The epidermis might necrose and slough in some regions of the graft. Generally, only the...
superficial areas of the graft have been lost and small areas of dermis surrounded by granulation tissue are present. The epidermis regenerates from migration of epithelial cells present in the remaining sebaceous glands, sweat glands, and hair follicles (Fig. 20).

Periodic bandage changes allow for a clean environment and recognition of graft failure. For many horses frequent bandage changes aid in comfort. Soaking the inner...
bandage with sterile saline for 5 minutes and then carefully removing the bandage prevents destruction of many grafts. The presence of purulent material on the initial bandage change does not have a detrimental effect on acceptance of individual grafts. Silver sulfadiazine in a 1% water-miscible cream is effective against most gram-positive and gram-negative organisms and may enhance wound epithelialization. Additional immobilization gained with a cast is usually unnecessary to facilitate acceptance of grafts after 10 to 14 days. Immobilization may, however, lessen edema and decrease the possibility of self-mutilation.8,96,97 Persistence in regrafting on horses that self-mutilate wounds has resulted in satisfactory wound healing in most cases.

SUMMARY

Complications of wounds and cosmetic surgery although frequent can be accurately managed with a combination of timely surgical and medical intervention to ensure the best possible outcome. The lack of soft tissue protection and a large quantity of susceptible synovial, tendon, ligament, and neurovascular structures make early and meticulous evaluation of limb wounds critical. Radiographs of traumatized areas should be performed in all cases of distal limb wounds. Devitalized bone subject to sequestrum formation may not be evident initially. Ultrasonography provides information about the details of soft tissue structures and radiolucent foreign material.

Chronic wounds should be considered infected and may become afflicted with sarcoid, Pythium spp, Habronema spp, or Draschia spp and rarely squamous cell carcinoma. Identification of pathologic tissue from a biopsy sample of the wound confirms the diagnosis. MRSA infections can consequently be difficult to treat and are associated with increased morbidity, mortality, and treatment costs, compared with infections caused by methicillin-susceptible S aureus strains. Penetrating wounds of the abdomen or thorax have a guarded prognosis resulting from the ensuing potential for infection and pneumothorax. Gunshot wounds limited to the skeletal muscles have a good prognosis, whereas injuries that involve vital organs decrease survivability.

Skin grafting is usually used following a period of open wound management and after healthy granulation tissue formation. Skin graft may be applied to fresh wounds that are vascular enough rapidly to produce granulation tissue. Failure to adhere to these basic principles in wound care results in poor graft survival.

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