1. Introduction

Veterinarians have several options for management of traumatic limb wounds in horses.\textsuperscript{1,2} Primary closure describes wound closure with sutures within a few hours of injury. Healing in such cases, termed primary (first intention) wound healing, provides optimal cosmetic and functional outcome as well as the most rapid return to work. A wound that is left open (i.e., not closed with sutures) heals by a combination of wound contraction and epithelization known as secondary (second intention) healing. Contraction is modest in limb wounds that have lost skin, hence the predominant method of closure in such wounds is by migration of epithelial cells from the wound margins. This is a notoriously slow process, ultimately resulting in an unaesthetic hairless scar of poor mechanical durability. Delayed closure, a third option for management of traumatic limb wounds, may be highly effective in selected cases.\textsuperscript{1–3} In this technique, the wound is originally left open, normally to reduce the risk of infection, and then closed at a later date. If the wound is closed before granulation tissue is visibly evident (normally 4–5 days), the procedure is termed “delayed primary closure,” and the outcome is considered primary healing (the same healing as occurs in a wound sutured primarily).\textsuperscript{4} If closed after granulation tissue is evident, the procedure is secondary closure and results in tertiary (third intention) healing.

Delayed closure of limb wounds is indicated in traumatic wounds that have had little or no loss of tissue but, for some reason, were not sutured primarily.\textsuperscript{1–3} Failure to close a wound primarily may be elected if a wound is seen shortly after injury but is considered to be highly contaminated with bacteria and foreign material and/or has severe local trauma, resulting in impaired local tissue defenses. Closure of such wounds primarily leads to a high risk of wound infection and dehiscence. If such wounds are left open for a few days before closure, the risk of infection is dramatically reduced with an outcome still considered primary wound healing. There is no substantial fibroplasia in a wound before 4 to 5 days after injury, so closure anytime before this point has minimal effect on gain of tensile strength. In other cases, failure to present the case until considerable time has elapsed allows substantial tissue edema and bacterial colonization of tissues, eliminating primary closure as a treatment option. These wounds have missed the “window” for primary closure but may be still be good candi-
dates for delayed primary closure. Secondary closure (after granulation tissue has formed in the wound) is an option for older wounds that were not sutured earlier or underwent dehiscence after primary closure. Delayed closure techniques can be used on wounds of the upper limbs or trunk, but these areas normally contract so well that this is unnecessary.

This report describes use of delayed closure techniques for limb wounds in horses.

2. Materials and Methods
Fresh wounds are candidates for delayed closure if there is little or no tissue loss, but there is a high risk of wound infection and dehiscence with primary closure. In such cases, wound preparation mirrors that used in wounds undergoing primary closure. The procedure is normally done with the horse standing under appropriate sedation and wound anesthesia (regional block or local infiltration). The skin around the wound is clipped and surgically prepped. The wound bed is ideally prepared by complete wound excision (en bloc debridement), the sharp removal of superficial tissues covering the entire surface of the wound (Figs. 1 and 2). This is the most effective technique for removing bacteria and particulate foreign material from the wound and for eliminating severely damaged tissues. Less aggressive (simple) debridement will be required in areas of wounds when vital structures such as tendons, nerves, or major vessels are exposed. In this case, grossly visible foreign material and devitalized tissues are removed. The wound should be copiously lavaged, using balanced electrolyte solution at a low pressure (gravity flow, syringe spray, squeeze bottle). High-pressure lavage such as that delivered by a pulsatile unit should be avoided because it may waterlog tissues. Dry gauze sponges are placed over the wound, and a pressure wrap is applied. The bandage is changed every 1 to 2 days, and the wound is gently cleansed by wiping with dry gauze sponges and sharp debridement as needed. Concurrent therapy includes regional limb perfusion with antibiotics (in cases with severe trauma or contamination or involving synovial spaces), systemic antibiotics, nonsteroidal anti-inflammatory agents, and tetanus prophylaxis.
Delayed closure is usually performed 4 to 5 days after wounding. Suitability of the wound for closure is based on visual examination. Tissues should appear healthy, with minimal swelling and only small amounts of nonodorous serous discharge. The skin around the wound is prepped, and the wound is desensitized with 2% lidocaine HCL. Additional debridement is performed if necessary, and the wound is thoroughly lavaged. Undermining of adjacent skin deep to the subcutaneous tissues may help closure in wounds less than 4 to 5 days old. The skin is closed by first placing a row of tension relieving sutures (vertical mattress sutures or pulley mattress sutures such as near-far-far-near, using a monofilament nonabsorbable suture (such as No. 0 or No. 1 polypropylene or nylon) 2 to 3 cm from the wound edge. Simple interrupted sutures (No. 00 polypropylene or nylon) are then used, placed close to the edge of the wound to effect good edge to edge skin apposition (Fig 3). The limb is kept in a heavy pressure bandage for 2 to 3 weeks. A cast is recommended for wounds in high motion areas (especially those of heel bulbs, dorsum of the fetlock, or involving the flexor tendons). Foot casts can be applied in standing horses for treatment of wounds of the heel bulbs and pastern area. Casts for wounds of the fetlock or metacarpus/metatarsus are applied under general anesthesia (Figs. 4 and 5).

Secondary closure is an option for older wounds that have been neglected early on or have undergone dehiscence after primary closure (Figs. 6 through 8). The closure technique is similar to that used for delayed primary closure, with a few exceptions. This repair is normally done under general anesthesia due to more extensive surgical manipulations and frequent need for casting. Most of the granulation tissue is surgically removed from the wound. A surgical incision is made at the junction of skin and granulation tissue. The granulation tissue composing the wound bed is then sharply undermined and discarded. Due to fibrosis and lack of pliability in tissues around the wound, skin closure is often challenging. Undermining of skin adjacent to the wound nor-
mally has little if any benefit. If tension is extreme, two rows of vertical mattress sutures (No. 1 polypropylene or nylon) can be pre-placed in staggered rows (echelon pattern). The skin edges are then apposed by temporarily bridging the wound with several penetrating towel clamps, and the pre-placed sutures are tightened and tied. A row of simple interrupted sutures (No. 00 polypropylene or nylon) are then placed for skin edge apposition. Pulley mattress sutures (e.g., near-far-far-near) can be used in lieu of the vertical mattress sutures. If tension is exceptional, the limb should be placed in a cast for 10 to 14 days; otherwise, a heavy bandage is acceptable. Drains are not normally used because these should be clean wounds at closure, and bandaging will prevent fluid accumulation in any dead space.

The wound is kept under bandage for 4 to 6 weeks, with a bandage change every 2 to 3 days. Horses with wounds that are healing primarily can begin hand-walking exercise at 3 weeks after closure and return to light work at 6 weeks.

3. Results
We use delayed primary closure in relatively few horses in our hospital (perhaps 2 per year), mostly because our wound case load is largely referred, complicated cases rather than first-opinion cases. Secondary closure is used more commonly (3–4 cases per year).

4. Discussion
If at all possible, secondary healing of limb wounds in horses should be avoided. Open wounds heal very slowly and are at risk for exuberant granulation tissue and other complications. The outcome of such healing often is an unsightly, fragile epithelial scar. If a horse has lost skin from a wound, then closure is usually not possible and secondary healing (sometimes augmented by grafting) is necessary. If there has been no skin loss, delayed closure techniques provide options beyond the window of primary closure. Traumatic limb wounds in horses managed by primary closure are at
high risk of infection and dehiscence. Indeed, a large clinical study determined that only 21% of sutured limb wounds in horses healed primarily.\(^4\) Leaving a fresh, highly contaminated wound open for a few days before closure allows free wound drainage and opportunity for ongoing debridement of devitalized tissues, reducing the risk of infection. As long as the wound is closed before the onset of fibroplasia at 4 to 5 days, there is no appreciable adverse effect to delaying closure.\(^5\) Secondary closure, although technically more challenging due to excess skin tension, similarly provides an additional option for management of long-standing limb wounds.

One could rightly argue that contraction will largely close distal limb wounds if no skin was lost by wounding. This is true in many cases, but healing time and wound appearance will be improved with primary healing, whether attained by primary closure or by delayed primary closure.

References and Footnotes


*Prolene, Ethicon, Somerville, NJ 08876.
*Ethilon, Ethicon, Somerville, NJ 08876.