Choosing the Best Approach to Wound Management and Closure

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KEYWORDS

• Horse • Wound • Primary closure • Secondary intention healing • Delayed closure

KEY POINTS

- Each wound requires an individual assessment to identify the most suitable approach.
- Clear client communication and good knowledge of the healing process are critical to achieving the best possible outcome for the horse.
- Primary closure provides the best cosmetic and functional outcomes for the horse and limits the cost and aftercare required by the owner.
- Second-intention healing is selected to manage wounds with heavy contamination or with extensive trauma/tissue loss.
- Delayed closure can be used when a wound is highly at risk of infection and dehiscence.

INTRODUCTION

Wounds account for a large portion of the caseload of an equine practitioner. The US Department of Agriculture found that skin wounds are the most common medical condition affecting horses[1]; this is also reported by UK horse owners.[2] Similarly, equine veterinarians in New Zealand and Australia report that 25% of their caseload is wound related.[3] In emergency situations, equine ambulatory practitioners often face the dilemma, Should I suture the wound or not? There is no easy answer based on well-defined rules and wound classifications. Each wound must be considered as a unique problem that requires a clinician to take into account all its characteristics to determine the best management approach. The aim of this article is to help the practitioner by providing the tools to decide which type of closure or healing is best in a given situation. An overview of the main criteria and the different approaches to wound closure is presented.

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FACTORS THAT INFLUENCE THE CHOICE OF TREATMENT

To select the optimal approach to manage a wound, a full clinical assessment of the patient and a careful examination of the wound are required. The decision to close or not to close a wound should be adapted to each wound and circumstance. Moreover, the veterinarian must recognize that the wound healing process in horses differs from that observed in other mammalian species.[4,5] These differences extend even to ponies, the latter being less susceptible to wound dehiscence, bone sequestrum formation, exuberant granulation tissue (EGT) formation, and delayed wound healing than are horses.[6] Faster and less problematic healing is thus expected for ponies compared with horses. Different factors can influence wound healing and the outcome of treatment; these must be recognized for a clinician to adapt his approach and to anticipate the evolution of the wound. Knowledge of these factors is prerequisite to effective client communication.

Patient-Related Factors

Full consideration of the health of the patient is necessary when attending a wound. Many factors can potentially influence the response to the attempted approach and its outcome. Advanced age of the patient does not seem to directly affect healing in horses.[7] Age-related diseases, however, influencing the systemic state of the patient must be taken into consideration because the consequences could impair healing (eg, Cushing disease). Patients who suffered substantial blood loss or are in shock after trauma may not be good candidates for early treatment of the wound. Rather, stabilization and improvement of the patient's systemic state are often first required to maximize the success of wound management. The nutritional status of the horse is of utmost importance because wound healing is an energy-demanding process. Patients with a negative metabolic status are more likely to experience impeded and failed healing.[7]

Wound-Related Factors

Each wound is unique and should be assessed to select the best approach for treatment. Many practitioners have learned that wounds less than 6 hours to 8 hours old can be closed with low risk of infection and dehiscence. This dogma finds its origin in laboratory animal and human studies from the nineteenth century and from World War II. This golden period concept, however, is no longer considered accurate and each wound must be evaluated in light of several factors in addition to duration.

The choice of treatment of a wound is always related to the wound's location, its type, and degree of compromise to structures underlying the skin. As demonstrated in previous studies comparing horses and ponies, wounds on the distal limb of horses heal differently compared with wounds located on the body.[5] Distal limb wounds usually show a more marked expansion/retraction phase in the early phase of healing,[8] which is followed by inefficient contraction and slow epithelialization.[9] A wound in this location is also more exposed to environmental contamination with foreign material due to its proximity to the ground. Moreover, EGT is more likely to develop in wounds on the distal limb[10] and in areas of high motion. The intrinsic characteristics of the wound (size, depth, orientation, and amount of tissue loss) influence the rate of healing and the selected approach for reconstruction. Similarly, identifying and managing seroma, hematoma, edema, and/or dead space are essential to limit the risk of infection and wound dehiscence. It is of utmost importance to assess the implication of underlying structures during wound evaluation. Wounds with synovial, pleural, abdominal, and/or sinus cavity implications are complicated wounds that

may require hospitalization for extensive and aggressive treatment.[7,11] The implication of bone, ligament, or tendon also requires a specific approach; for example, bone exposure and periosteal damage often lead to the formation of a sequestrum during healing (see Randy B. Eggleston's article, "Wound Management: Wounds with Special Challenges," in this issue). The sequestrum acts as a foreign body that impedes healing, promotes inflammation and infection, and encourages the development of EGT.[12] Ligament and tendon are poorly vascularized structures that are, therefore, good foci of uncontrolled infection.[13] Movement of a tendon within a wound promotes formation of different planes of granulation tissue[13] as well as EGT,[12] thereby impeding healing. Wounds involving damage to underlying tendons or ligaments often require immobilization. These particular situations must be recognized to educate owners about their influence on the outcome of the wound management (see Randy B. Eggleston's article, "Equine Wound Management: Bandages, Casts, and External Support," in this issue).

Tissue perfusion around the wound and within the wound bed is critical to an effective healing process. By recognizing situations where blood flow is impeded (eg, trauma to local vessel and hypovolemia), the clinician should adopt an approach to optimize healing and anticipate complications. Optimal tissue perfusion and oxygenation are essential for the elimination of bacteria, collagen synthesis, and epithelialization.[7] Apart from restoring normovolemia when necessary, healing can be optimized by removing avascular and necrotic debris and débriding the wound bed until bleeding healthy tissue is reached.[7] By doing so, healing progresses more quickly and efficiently.[14]

The risk of infection in horses' wounds is high because horses are housed in environments harboring bacterial populations able to colonize open wounds. Moreover, foreign bodies are often found in horses' wounds. Infection is a major cause of dehiscence and delayed wound healing because bacterial enzymes and endotoxins interfere with the healing process and promote chronic inflammation.[7] There is also evidence of the presence of biofilm in equine surgical and accidental chronic wounds, suggesting that biofilm might impair wound healing in horses.[15,16] Early identification of uncontrolled infection, therefore, is critical to avoid the formation of biofilm and delayed healing.[17,18] The quantification of the wound bioburden is often unpractical and unrealistic in many clinical settings and the practitioner must rely on the clinical signs of infection, such as heat, swelling, discharge, odor, and pain from the wounded area. Irregular tissue, reddish tissue, and EGT also can indicate ongoing uncontrolled infection within the wound bed. The first step of effective wound bioburden control involves aggressive débridement, irrigation, proper drainage, and wound protection, when possible (see Karl E. Frees' article, "Equine Practice on Wound Management: Wound Cleansing and Hygiene," and Britta S. Leise's article, "Topical Wound Medications," in this issue). In cases of uncontrolled infection, antimicrobial strategies (antibiotics and specific dressings) combined with wound revisions are recommended (see Britta S. Leise's article, "Topical Wound Medications," and R. Reid Hanson's article, "Medical Therapy in Equine Wound Management," in this issue).

Wounds are frequently managed by owners before a patient is presented to a veterinarian. Knowledge of prior treatments can be helpful to understand and predict the behavior of the wound. Some topical treatments commonly used by horse owners (caustic agents, anti-inflammatory drugs, and antibiotics) may have negative effects on the healing process, depending of the timing and duration of their use.[7]

Taking into account all these factors helps the clinician choose the best approach to wound management and the decision to close or to leave open a defect.

Factors influencing wound management:

- Systemic state
- Concurrent disease
- Nutritional status
- Nature and location of the wound
- Characteristics of the wound
- Involvement of underlying structures
- Tissue perfusion
- Contamination
- Prior treatments

PRIMARY CLOSURE AND DELAYED PRIMARY CLOSURE

Primary Closure

Primary closure refers to closing the wound immediately after cleansing, débriding, establishing proper drainage and immobilization, as needed.[18,19] If successful, this approach provides the best cosmetic and functional outcomes for the horse because bringing wound edges together covers the defect, protects from further contamination, and decreases the amount of tissue repair needed to re-establish skin function and integrity. Primary closure, however, can sometimes fail due to dehiscence caused by infection. A correct wound evaluation and preparation is, therefore, mandatory before any attempt at primary closure.

Scant information is available in the literature regarding the outcome of this type of wound closure in horses. In a retrospective study of first intention healing of traumatic wounds in horses and ponies, more than 60% were located on the distal limb. Primary closure was successful, with no dehiscence, in only 26% of horses and 41% of ponies.[6] Primary closure is also associated with superior cosmetic and positive athletic outcomes in horses with a wound on the distal limb involving traumatic laceration of the extensor tendons.[20] In the authors' personal experience, many wounds treated by primary closure show a minor degree of focal wound dehiscence or infection that can be quickly handled with local therapy. The authors consider these wounds as successfully treated by primary closure.

Primary closure is often the treatment of choice for fresh and minimally contaminated wounds with a good blood supply, moderate tissue loss, and minimal tension on the wound edges.[18] These typically include head, body, and upper limb wounds; wounds with a well-vascularized skin flap; and some distal limb wounds that meet these favorable criteria. Wounds from sharp trauma are also candidates for primary closure. On the other hand, primary closure are not suitable for wounds with the following characteristics: heavy contamination, edema, extensive tissue loss, crush, and abrasive trauma. Nonetheless, some wounds that, in theory, are not good candidates for primary closure because of high contamination or compromised blood supply may still be considered for early suturing. This is usually the case for wounds occurring in the metacarpal/metatarsal area (eg, degloving injury), which suffer from high skin tension and consequently few to no options for reconstruction when allowed to heal by second intention.[21] When primarily closed, the skin flap acts as a temporary biological bandage meant to protect underlying

critical structures (bone, tendon, and so forth) from desiccation and to encourage formation of a protective healthy layer of granulation tissue.[18] It is particularly important, in this type of wound, to achieve good control of contamination through débridement and ventral drainage. In these cases, it is critical to prepare the owner for the potential failure and complete dehiscence of the attempted primary closure, a situation ultimately requiring management by either delayed secondary closure (discussed later) or second-intention healing.

Characteristics of wounds suitable for primary closure:

- Minimal contamination
- Good blood supply
- Moderate tissue loss
- Moderate tension on wound edges

Types of wounds:

- Fresh
- Head
- Flap wounds (neck, flank, thorax, and upper limb)
- Sharp trauma
- Some distal limb wounds
- Metacarpal/metatarsal degloving injuries

Tips for successful primary closure:

- Effective débridement and irrigation
- Reduction of dead space
- Proper drainage
- Relief of tension
- Minimization of suture material
- Immobilization, when possible

Delayed Primary Closure

In many situations, as an alternative to first-intention healing, closure can be delayed for a few days (1–3 days) to allow better preparation of the wound bed to increase the chance of success of closure. This is referred to as delayed primary closure.[18] Repeated débridement and irrigation reduce the bacterial burden and prevent the formation of biofilm.[17] Specific types of dressing material and antimicrobial therapies also can be used during this period of delay, to manage infection (see Britta S. Leise's article, "Topical Wound Medications," and R. Reid Hanson's article, "Medical Therapy in Equine Wound Management," in this issue). Edema can be managed with hypertonic saline dressings.

To the authors' knowledge, no studies have been conducted in horses to assess if a superior outcome can be expected after delayed primary closure compared with primary closure. The medical literature suggests that delayed primary closure may reduce the occurrence of surgical site infection in specific wound scenarios in human patients, but definitive evidence has yet to be provided.[22–24] A recent systematic review from the Cochrane database concluded that there is currently no evidence to guide clinical decision making regarding the timing for closure of traumatic wounds.[25] Repeated débridement and irrigation prior to closure, however, are certainly beneficial because wounds in horses are subject to heavy contamination.[7]

The major drawback of delayed primary closure is that the veterinarian must deal with the initial wound expansion that occurs in the first weeks of healing in horses.[5] This gradual increase in size of the wound surface area could impede complete closure of the wound but, ultimately, partial closure still is preferable to second-intention healing. It may be possible, in some cases, to limit wound expansion by placing retention sutures across the wound gap during the waiting period or by undermining a wound's edges before undertaking delayed primary closure.[18]

Delayed primary closure is a suitable approach for wounds that could be closed by primary closure but are heavily contaminated or excessively swollen, thereby increasing the likelihood of dehiscence. This is the case, for example, of limb wounds with extensive soft tissue trauma and inflammation due to struggling[18] or of wounds located over open synovial cavities (see Elsa K. Ludwig and Philip D. van Harreveld's article, "Equine Wounds Over Synovial Structures," in this issue). Delayed primary closure could also be indicated for patients who suffered substantial blood loss or are in shock after the trauma. When a patient's systemic state improves and stabilizes, wound closure can be safely attempted.

Characteristics of wounds suitable for delayed primary closure:

- Up to 1 day to 3 days after trauma
- Wounds suitable for primary closure but with marked
  - Contamination
  - Edema
  - Drainage
- Substantial blood loss
- Shock

Tips for successful delayed primary closure:

- Repeated débridement and irrigation
- Use of hypertonic saline dressings
- Use of antimicrobial therapies
- Use of retention sutures
- Tissue undermining

SECOND-INTENTION HEALING AND DELAYED SECONDARY CLOSURE

Second-Intention Healing

In most cases when primary or delayed primary closures are not an option, it is because the wound is grossly contaminated and/or suffering moderate to severe tissue loss. Apposition of the wound edges, therefore, is not possible and wounds must heal through granulation, contraction, and epithelialization. This type of healing is referred to as second-intention healing.[18] Second-intention healing also pertains to wounds that have undergone partial or complete dehiscence of a primary closure. These wounds still require good débridement and cleansing to reduce contamination or infection as well as proper ventral drainage. Second-intention management often requires multiple interventions to stimulate and control the progression of healing, because they are more prone to prolonged healing time. Immobilization, when possible, may be necessary to minimize damage to the wound bed caused by motion (see Randy B. Eggleston's article, "Equine Wound Management: Bandages, Casts, and External Support," in this issue). This wound management approach might be chosen by owners concerned by the cost of an initial primary or delayed primary closure. Costs associated with multiple and repeated veterinary interventions required to ensure proper healing, however, may surpass those of a successful primary closure.

Second-intention healing is not ideal because wounds in horses heal primarily by epithelialization rather than by wound contraction, especially when located on the limb.[9] This leads to the formation of a more extensive and weaker scar (that can withstand a maximum load of only 60% of the breaking force of normal intact skin[26]), in which normal skin adnexa (pigmentation, hair, sweat, and sebaceous glands) are not regenerated.[8] Body wounds usually heal with an acceptable functional and cosmetic outcome, except for those involving severe trauma with extensive tissue loss.[18] Body wounds also heal significantly faster than do wounds on the limbs.[9] Wounds on the distal aspect of the limb heal poorly by second intention and often form EGT,[6] which require multiple débridements to allow epithelialization and contraction to ensue.

Wounds with extensive tissue loss and gross contamination require second-intention management.[18] This also is normally the approach selected for wounds of the axilla and groin as well as burn injuries and wounds caused by pressure or entrapment.[18] Degloving injuries of the limb, which suffer partial or complete dehiscence after primary closure, must also heal by second intention.[21]

Characteristics of wounds suitable for second-intention healing:

- Gross contamination
- Extensive tissue loss
- High tension on wound edges

Specific types of wounds:

- Axilla
- Groin
- Burn injuries
- Pressure/entrapment injuries
- Metacarpal/metatarsal degloving injuries

Tips for second-intention healing:

- Effective débridement and irrigation
- Proper drainage
- Immobilization, when possible
- Early stimulation of fibroplasia/granulation
- Trimming of EGT

Delayed Secondary Closure

Once a bed of healthy granulation tissue has filled a wound defect when healing by second intention, it is possible to attempt to bring together and suture the wound edges. This is referred to as delayed secondary closure.[18] The goal is to speed up the healing process, to avoid the formation (or recurrence) of EGT, and to aim for a more cosmetic and functional outcome. Delayed secondary closure requires a combination of partial resection of granulation tissue, undermining of wound edges, tension-relieving suture patterns, proper distal drainage, and, in some cases, immobilization of the treated area. Delayed secondary closure is suitable for wounds having a limited loss of tissue and presenting healthy granulation tissue (absence of infection, smooth, and well vascularized).

Delayed secondary closure is often chosen for heavily contaminated or infected wounds that have previously been managed by an owner. Common examples are heel bulb or pastern lacerations.[18,27] These types of wounds heal well with delayed secondary closure supported by proper immobilization (cast) (see Randy B. Eggleston's article, "Wound Management: Bandages, Casts, and External Support," in this issue). Delayed secondary closure can also be used for revision of chronic wounds. Delayed secondary closure is not, however, suitable for wounds in areas of high skin tension (eg, metacarpal/metatarsal area) or characterized by severe loss of tissue.[18]

Characteristics of wounds suitable for delayed secondary closure:

- Revision of wounds healing by second intention
- Healthy granulation tissue
- Minimal skin tension

Tips for successful delayed primary closure:

- Trimming of granulation tissue
- Proper drainage
- Undermining
- Tension-relieving suture patterns
- Immobilization

SUMMARY

Unfortunately, there is no simple and straightforward algorithm (**Fig. 1**) to determine if a wound should be closed or not. Each wound requires an individual assessment to identify the most suitable approach. Many factors determine the rate and outcome of the

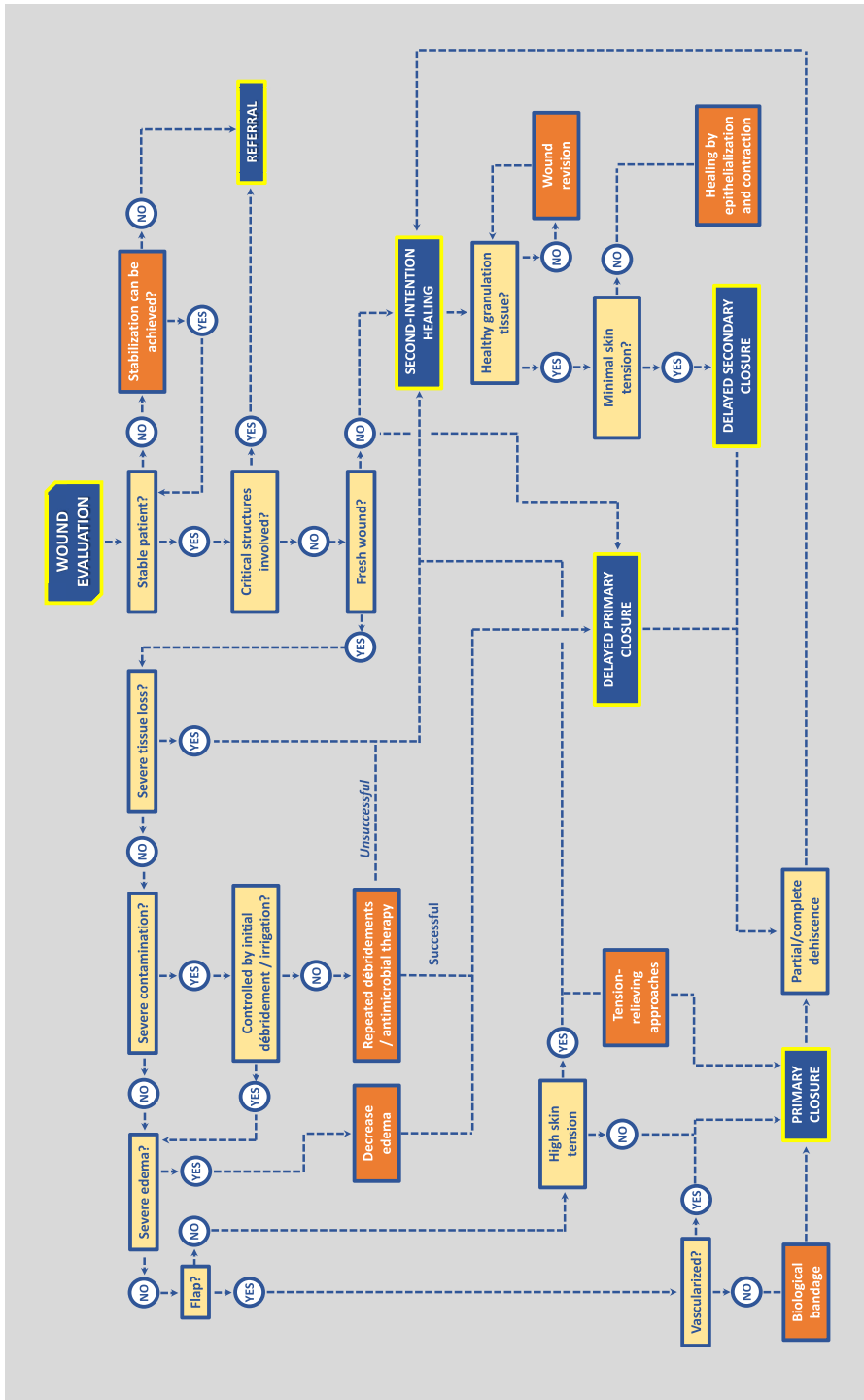

Fig. 1. Wound treatment approach algorithm.

healing process and these must be identified when a wounded horse is first presented for examination. Clear client communication and good knowledge of the healing process should help the practitioner achieve the best possible outcome for the horse.

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