cpdsolutions
transferring knowledge through excellence in training

Getting it Together - Wound Management and Closure in Dogs and Cats Mini Series

Session 1: Step by Step - Logical Open Wound Management

Ronan Doyle MVB CertSAS MRCVS DipECVS
European Specialist in Small Animal Surgery
RCVS-recognised Specialist in Small Animal Surgery

Skin Structure

Skin is composed of an outer stratified epithelium and an underlying fibrous dermis. The epidermis is of variable thickness but is generally thicker in areas without a hair coat especially at the nasal planum and the digital pads. The thickness of the skin is directly related to the thickness of the dermis and varies with age, sex, breed and area. The thickest skin (and therefore dermis) in the dog and cat is over the dorsal midline, head and neck, whereas the thinnest is on the ventral surface, the medial aspects of the limbs and the inner pinna.

Skin is an elastic tissue and this quality is dependent on the arrangement of the dermal collagen. As a progressively larger load is applied to skin, it stretches as convolutions in the dermal collagen flatten, followed by alignment of the collagen fibres parallel to each other and finally stretching of the aligned collagen fibres. This ability to stretch is utilised in pre-stretching skin before reconstruction. The most pliable skin is over the dorsal neck, axilla and flank, whereas the least pliable is over the tail, pinnae and the pads.

Within the skin are the adnexa including hair follicles, sweat glands and sebaceous glands. The specialised glands include the mammary glands and the circumanal glands. The hair follicles are located within the dermis and may extend into the underlying subcutaneous tissue. The wall of the hair follicle is continuous with the epidermis, so that if the main portions of the epidermis are lost then re-epithelialisation can occur from migration of epithelial cells from the follicles (as well as from the sweat and sebaceous glands). Hair growth rates vary with more rapid growth in winter. Short canine coats take about 130 days to regrow, however in long haired dogs regrowth can take up to 18 months.

The subcutaneous tissue is composed primarily of fat with loose collagen and elastic fibres. A key component of this layer over much of the body is the panniculus musculature (the cutaneous muscle). This is present over most of the head, neck and trunk but is lacking over the middle and distal regions of the limbs (where the skin is more firmly attached to the underlying structures). These muscle fibres penetrate the dermis and allow voluntary movement of the skin. The main paniculus muscle is the cutaneous trunci that originates in the gluteal region and extends cranially to the axilla.

The blood supply to the skin is divided into the deep subcutaneous plexus, the middle plexus and the superficial plexus with interconnections between all three levels. It is the deep subcutaneous plexus that is the key layer as it is from here that branches extend up to the middle and superficial layers. Where there is panniculus muscle the deep subcutaneous plexus is deep and superficial to it. In dogs and cats the deep subdermal plexus is supplied by the direct cutaneous vessels that run parallel with the overlying skin. This is different from humans where the blood supply to skin is supplied by musculocutaneous vessels that penetrate up from the underlying muscle. Knowledge of the positions of these direct cutaneous vessels is very important when planning wound closure to prevent iatrogenic damage to the blood supply to a section of skin and also when using axial pattern flaps.

The Surgical Perspective

The importance of the panniculus muscle is that the major blood supply to the overlying skin (the deep subdermal plexus) is intimately associated with it. The panniculus muscle must be preserved when undermining skin.

Where there is no panniculus muscle the deep subdermal plexus is associated with the subcutaneous fat on the deep face of the dermis. Skin should therefore be undermined below this layer. This may mean undermining below the outer muscle fascia if the skin is very closely associated with it.

Using an atraumatic surgical technique such as careful blunt dissection helps to minimise damage to the subdermal plexus. Avoid damage to the direct cutaneous vessels when dissecting.

In traumatised skin, the blood supply will be compromised by oedema, bruising and infection. Therefore wait until there is restoration of a good blood supply before extensive dissection or reconstruction is performed.

Understanding the Process of Wound Healing:

Effective wound management relies upon an understanding of the stages of wound healing and an ability to identify these stages within a wound. From this the key issues that are affecting wound healing can be recognised and effective steps can be taken to aid wound healing. This informed 'problem-solving' approach is a highly effective way to deal with the vast majority of wounds encountered in practice.

Wound healing a complex and dynamic process which is initiated, mediated and controlled by a complex interaction of cytokines and growth factors. This enormous field of study is incompletely understood, however the surgeon needs a good working knowledge of this process. To aid this wound healing can be divided into the following four stages of: 1) Haemorrhage/Coagulation/Initiation; 2) Inflammation/Debridement; 3) Reparative; and 4) Maturation.

The **key skill** for the surgeon is recognition of each of these stages and to have a working knowledge of what is occurring during each of them.

1. Haemorrhage/Coagulation/Initiation Stage

The immediate haemorrhage after trauma flushes the wound surface and fills the wound. The blood clot that forms helps to protect the wound from trauma and acts as a barrier to infection. This clot forms a provisional extracellular matrix (ECM) that forms the framework for early organisation of the wound as cells migrate into the site. The fibrin within the clot stabilises the wound edges and provides some initial wound strength. In a sutured surgical wound, it is the fibrin clot that prevents bacterial migration into the deeper wound; stabilises the wound edges (along with the skin sutures); and also allows epithelial cells to migrate across the wound under its protection.

2. Inflammation and Debridement Stage

Inflammation is characterised by migration of leucocytes into wound and begins from 6 hours after the injury. In the early stages neutrophils predominate and the classic signs of inflammation (redness, pain, swelling and heat) can be identified. The combination of debris, extracellular fluid and dead neutrophils makes up the wound exudate (pus) visible at this stage. With time, monocytes migrate into the wound and begin to predominate. The degree of heat, pain, swelling and redness subsides and the monocytes differentiate into wound macrophages. Macrophages are highly effective at debridement of foreign material, bacteria, damaged cells/ECM, and depleted neutrophils. Macrophages are essential to wound healing as they control the wound environment by cytokines that modulate the wound from the inflammatory to the reparative phase with the formation of granulation tissue.

The appearance of the wound during the inflammatory/debridement phase is of inflammation, a blood clot or denuded wound surface and a serosanguinous to purulent discharge. This apparent lack of activity within the wound led to it being traditionally called the lag phase, whereas in fact it is a stage of considerable activity before the reparative phase. It is important to remember that a discharge from an open wound is a normal finding and an indicator of an active wound healing process.

If the wound edges are apposed and there has been minimal trauma, devitalised tissue or infection (as with a surgical wound), the inflammatory phase is minimal.

3. Reparative Stage

Granulation tissue formation is the most obvious feature of the Reparative stage and characterised by the proliferative processes of fibroplasia and angiogenesis. Fibroblasts proliferate and migrate from surrounding healthy tissue into the wound. Wound fibroblasts do not survive in adverse conditions; therefore fibroplasia will be delayed if there is a poor wound environment. With fibroplasia there is the simultaneous process of angiogenesis to supply the requirements of the fibroblasts. Angiogenesis is the ingrowth of capillaries from the surrounding pre-existing vessels at the wound edges and again modulated by wound macrophages.

The shift from the inflammatory stage to the reparative stage usually occurs by day 3-5 and is identified by the formation of granulation tissue which should have very pink, granular and slightly moist appearance. Remember however that the rate of development will vary depending on the degree of inflammation/infection present and vascularity of the surrounding tissue (muscle produces granulation tissue faster than bone/tendon). Granulation tissue is highly resistant to infection due to its excellent vascularity. It is also the ideal surface for epithelial cells to migrate across, although this relies on a flat surface to the wound. Specialised fibroblasts on the surface of the granulation tissue called myofibroblasts are able to shorten in length and allow contraction of the wound to occur. Prevention of inflammation during the reparative stage is important to achieve wound progression and prevent deterioration. Wound exudates contain high levels of protease enzymes which can be detrimental to the wound in excess, therefore control of exudate is very important during this stage of wound healing.

Contraction of the wound is visibly evident by 5 to 9 days after injury but depends on a good granulation tissue bed (with active myofibroblasts), attachment of this to the skin edges, and mobile elastic skin around the wound. Contraction ceases when the wound is closed or when the tension in the surrounding tissues overcomes the strength of contraction.

Epithelialisation is the other key event that is occurring during the reparative stage. In the very early wound phases epithelial cells migrate from the periphery of the wound. A closed sutured wound can be bridged by epithelial cells within 24-48 hours, whereas with an open wound epithelialisation may not be noted until 4-5 days after injury. Epithelial cells are fragile and require an adequate surface over which they can migrate (such as granulation tissue within a full thickness open wound). Behind the initial migrating epithelial cells, proliferation of epithelial cells occurs at the wound margins 1-2 days after injury, but this is generally not visible until 4-5 days as a pink smooth margin around the wound. The epithelial cells leapfrog over each other until the wound is covered with a thin epithelial surface at which further migration is inhibited. This is essentially a monolayer of cells over the wound surface and as such is extremely fragile especially to friction. This layer then thickens and then differentiates further become a keratinised surface. With very large full thickness wounds this process may take weeks to months and ongoing trauma can leave a central area of chronic granulation tissue.

4. Maturation Stage

An open wound becomes closed once there is an adequate covering of epithelium, but considerable healing still needs to occur as the wound matures. The cellular content of the tissue reduces as the cells die off and the collagen needs to rearrange and mature. This remodelling of the collagen fibres occurs as they become thicker and develop more cross linkages. Collagen will rearrange along lines of tension and there is a very gradual increase in strength as the rearrangement occurs. By the end of maturation, which may take months to years, the maximal strength of the wound is usually no more than 80% of normal.

Initial Assessment and Management

The initial assessment and management of a wound can be critical to the subsequent healing of the tissue. The goal is to achieve the most rapid healing possible to allow a rapid return to function. However management of the whole animal is obviously more important than just managing the wound. A complete history, clinical examination and appropriate diagnostic testing allow identification of concurrent or underlying problems. A balanced approach is where the systemic problems are diagnosed and managed, while the wound has appropriate first aid treatment. Neither is managed to the exclusion of the other as obviously systemic derangements will negatively influence wound healing just as major wound complications can have major systemic consequences. On admission the wound can be covered with sterile dressing to prevent further contamination and drying. Broad spectrum systemic antibiotics can also be administered with seriously contaminated wounds, but these become unnecessary once there is a healthy granulation tissue bed. Good analgesia is also essential to improve comfort and decrease stress with opioids being particularly suitable. Wound assessment is then performed under sedation or general anaesthesia once the animal is reasonably stable.

<u>Acute Wound Management Plan</u>

1. **Initial wound evaluation**

a. *Type of wound and extent of injury*

Wounds are initially classified as either open or closed. Closed wounds are associated with contusions and crushing injuries, and although there may not be an open skin wound there may be very significant injuries to the skin and underlying tissue. Open wounds can be classified according to their aetiology: Abrasions, Avulsion, Incision, Laceration, Burns, and Puncture wounds

b. *Evidence of contamination/infection*

This will delay or lead to a deterioration in the progression of wound healing

c. *Adequacy of blood supply*

This is essential for the viability of the wound, however in the initial few days after injury (especially for degloving and avulsion injuries) the adequacy of the blood supply to the injured tissues can be difficult to assess. It is best to avoid aggressive debridement, especially of skin, until the viability of the tissue is clear and this may take 2-5 days. Stabilising avulsed skin (by sutures or bandaging) is important as movement of questionably-viable skin will push it into necrosis

d. *Determining the stage of wound healing*

Critically assessing the stage of wound healing is a key skill. Ask yourself lots of questions: Is there evidence of inflammation? Is this appropriate or for longer than expected? What are the reasons for this and can these be resolved? Is there granulation tissue? Is there epithelialisation? Can contraction occur? If not, why not? This assessment and knowing the stage of healing directly informs the management of the wound.

2. Debridement and Lavage

Devitalised tissue, foreign bodies and bacteria prolong the inflammatory phase and promote infection. Removal of this material therefore helps to move the wound into the reparative stage. Debridement and lavage is used to try to convert the wound to as clean a wound as possible. Both these techniques are used in combination throughout the procedure.

Inadequate debridement is the most likely cause of a prolongation of the inflammatory phase and delays in wound healing. However the most important debridement that occurs within the wound during the inflammatory stage is the microscopic autolytic debridement performed predominantly by the macrophages. Modern bandage techniques, which emphasise maintenance of a moist wound environment, aim to create ideal conditions for autolytic debridement.

Lavage of the wound is a form of debridement that allows the dilution and removal of foreign debris, devitalised tissue, bacteria, wound exudate and pus. Lavage is used to mechanically remove this material to allow clearer evaluation of the wound. This can be useful in the later stages of wound healing to remove excess wound exudates and devitalised cells. The default lavage solution is always either sterile saline or Hartmanns solution with this nearly always preferable to lavage with antiseptics.

3. Further evaluation and decision to close wound or manage open

Following debridement and lavage, further evaluation of the wound and decisions regarding the future management of the wound need to be made. The key decision is whether the wound can be closed or managed open. The decision to close the wound requires either a clean sterile wound (as with an incision) or a wound that has been converted to a clean state. Ongoing drainage is also required in all but the most superficial wounds.

If the wound is to be managed open at this initial stage, then an initial plan for subsequent closure needs to be determined. This may be delayed primary closure, once the inflammatory stage is subsiding; or secondary closure, once there is granulation tissue present. In both these cases the wound bed or granulation tissue may be partially debrided or completely excised before closure.

The decision regarding ongoing wound management has major implications as it impacts on the amount of work required by the vet, the morbidity for the animal, and the management and costs required of the client. A clear assessment of the situation is needed and a thorough treatment plan needs to be formulated. Avoid using ongoing open wound management and eventual second intention healing as the default for wound closure as the total work and costs involved can be very considerable and the care can be over many months. At this stage a decision to refer may need to be made depending on the surgeon's experience, the animal's status and the financial implications.

If the decision is for ongoing open wound management, a clear plan as to when this will be converted to a reconstructive closure or continuation to second-intention healing is required.

<u>Ongoing Open Wound Management</u>

Effective wound management relies upon an understanding of the stages of wound healing and an ability to identify these stages within a wound, as discussed. In addition we looked at an acute wound management plan, which encompassed the steps of initial wound evaluation, debridement/lavage of the wound, and then making a decision to either close the wound or manage it as an open wound. The focus now is how to continue to manage the open wound in a logical manner. This requires ongoing assessment of the wound, which then informs the bandage choice by the veterinary professional.

Open wound management is an area which has undergone considerable research in the last 30 years with a resultant plethora of new technologies, products or techniques. Most of these products have been designed with the chronic non-healing human wound in mind, which is a very different situation to the majority of wounds that are encountered in our veterinary patients. This often leads to a tendency to apply the 'newest' treatment with a failure to fully appreciate their effect or appropriateness for the local wound environment. Similarly wound management dependent on outdated theories or therapies will often be to the detriment of the wound.

Logical Open Wound Management

Open wounds in small animals will often heal regardless of what we bandage them with. Instead of considering that we are speeding-up the process of wound healing, we should instead see our role as supporting the process of wound healing and actively removing barriers to healing, so that the wound heals as quickly and effectively as possible. We should therefore know how the wound healing stages should be progressing and actively try to support these stages with our interactions or bandage choices. We also need to set goals for the wound, such as when we can convert to surgical closure or whether the goal is allowing the wound to heal completely by open wound healing, also known as second-intention healing.

The open wound is managed by ongoing assessment and appropriate bandage selection. Initially and then at each bandage change, I assess 5 parameters, which then inform my choice of bandage, in particular the layer of the bandage in immediate contact with the wound (the primary contact layer). These parameters are:

1. ***The degree of inflammation within the wound***
   - ⇒ Ongoing or increased inflammation prevents the development of the reparative stage of wound healing.
   - ⇒ Intervention is needed at each bandage change or by the primary dressing to debride foreign or necrotic material which can perpetuate the inflammatory stage of healing.

2. ***The degree of exudate coming from the wound***
   - ⇒ The inflammatory and reparative stages of wound healing proceeds best in a warm, moist environment. This is the concept of ‘moist wound healing’. Wound exudate generally provides the appropriate ratio of proteases, protease inhibitors, growth factors and cytokines for each stage of wound healing.
   - ⇒ However excess wound exudate needs to be removed as it can contain excessive proteases that can damage the wound by increasing inflammation and can also lead to maceration of the surrounding skin. The aim is to keep the wound ‘bathed’ in exudates, but not ‘drenched’ in them, and appropriate absorptive bandages can successfully achieve this.
   - ⇒ Conversely a dry wound can slow down wound healing and can often occur due to an inappropriate dressing drying out the wound surface.

3. ***The presence and quality of granulation tissue***
   - ⇒ An <u>essential</u> wound management skill is the identification and monitoring of the growth and quality of granulation tissue, as its initial presence indicates the beginning of the reparative stage. Good healthy granulation tissue is desirable as it is highly resistant to infection and allows contraction and epithelialisation to proceed rapidly.
   - ⇒ Granulation tissue needs protection to prevent damage to fragile capillaries and epithelial tissues
   - ⇒ Chronic granulation tissue can appear pale and dry and has reduced blood vessels and lower cellular activity. This can delay the later stages of wound healing such as contraction and epithelialisation. Surface debridement (with a blade or with a debriding bandage such as a wet-to-dry) should help re-stimulate activity in the granulation tissue bed if this is present.

4. ***Assessment of the skin edges***

⇒ Adherence of the skin edges to the underlying granulation tissue is essential for the processes of contraction and/or epithelialisation to occur .

5. ***The degree of epithelialisation***

- Epithelialisation needs a smooth granulation bed with well adhered wound edges to proceed. It is identified as a pale pink area at the wound edge or a near translucent film at the skin edge). The new epithelium is fragile and needs protection to prevent frictional damage and dessication.

Bandaging wounds

Bandages are required to manage the wound surface (maintain the primary contact layer and absorb exudates) and to protect the wound from excess movement, contamination and self-interference. Obviously strict care is needed by veterinary professionals and the owner to prevent complications such as slippage, consumption of the bandage by the patient and ischaemic injuries.

The bandage construction is of a primary layer, the purpose of which is to support wound healing. This is followed by a secondary layer that may absorb exudates, provide padding and support the area. This is usually made of woven rolled padded material or cotton wool. The final tertiary layer is to secure and compress the secondary layer. This is usually a non-adhesive conformable bandage. Correct bandage construction is a skill not to be underestimated as poorly constructed bandages can lead to ischaemic injuries and possibly loss of the limb.

Bandaging in more difficult areas such as the perineal, rump, axilla and inguinal region may utilise a tie-over type dressing. This is constructed by placing suture loops around the wound approximately 2-4cm from the wound edges. The primary dressing layer is then placed on the wound surface with additional layers of absorptive material (such as large gauze sponges). This is secured by interlacing suture material or tape between the suture loops, crisscrossing over the secondary material.

Other options for difficult areas include conformable netting type bandages, body coats and adhesive dressings. In areas where motion will be to the detriment of the wound, bandages may be augmented with splints or half-casts. In areas with major orthopaedic injury (as with distal limb shearing/degloving injuries) orthopaedic implants, such as external skeletal fixators or bone plates, are used to stabilise the area.

The following list of primary wound dressings is focused on the options for each stage of wound healing. It is not an exhaustive list and is based on the author’s and his colleagues experience. For a more extensive discussion on the various properties, advantages and disadvantages of primary wound dressings, the reader is referred to the reading list. I also do not advocate any particular brand of bandage material.

The best policy is to select dressings according to the state of the wound following assessment. Instead of always moving towards the newest bandage, building experience and confidence with a smaller selection of bandages is preferable (and also is more efficient use of stock levels in the practice!). Many bandages have been designed with the human patient in mind and often do not justify the expense involved, although there can be specific occasions where they are indicated, such as with the multi-resistant infected wound in an old or immunocompromised patient. The objective in dogs and cats is to promote normal healing to progress and avoid dressings that are likely to hinder the process - as a general rule KEEP IT SIMPLE!

Bandages Applicable to the Stage of Wound Healing:

1. Inflammatory/debridement stage

The aim is to minimise the inflammatory/debridement phase and promote the development of the reparative stage

Role of primary contact layer:

⇒ Ongoing debridement
⇒ Control infection
⇒ Remove excess exudate
⇒ Manage oedema
⇒ Prevent drying
⇒ Protect area

Options:

⇒ Wet-to-Dry dressing – this is a dressing that allows mechanical debridement of the wound surface. This is achieved by placing cotton surgical swabs moistened with sterile saline onto the surface of the wound with secondary layers of dry absorptive dressing material. As the swabs dry the surface layer of the wound wicks up into the bandage and this is then removed (under good analgesia/sedation/anaesthesia) generally every 24 hours (or 12 hours for highly exudative wounds). This is effective at mechanically debriding a contaminated early open wound in a cheap and straightforward manner. However I rarely use this for longer than 48 hours on the wound, as after this it is too destructive to the wound surface and delays onset of the reparative stage. After this dressing I switch to a moisture retentive dressing.

⇒ Moisture retentive dressings – by maintaining a moist warm wound surface these dressings support autolytic (cellular) debridement.

- Polyurethane foam dressing
- High absorptive capacity dressing – effective at managing highly exudative wounds
- Hydrogels (+ either a non-adherent dressing or a foam dressing) – these are primarily indicated to provide a moist wound environment especially if the wound is drying out.
- Alginate dressings (+ either a non-adherent or a foam dressing)

- ⇒ Medical-grade Honey (+ a dressing such as a polyurethane foam dressing to maintain this in place). This assists autolytic debridement and has an antibacterial effect. This is probably my dressing of choice in an infected/heavily contaminated wound environment
- ⇒ Negative Pressure Wound Therapy – application of a closed vacuum to the wound surface. This is useful for managing difficult to bandage wounds and/or highly exudative wounds as the dressing sucks itself onto the wound and removes excess exudate. It requires complete sealing of the wound to allow a wound pump to create a seal and negative vacuum pressure.
- ⇒ Medicinal Maggots – these are very rarely indicated but potentially useful for highly necrotic or multi-drug resistant infected wounds

Frequent bandage changes are necessary to remove wound exudate and prevent water logging of dressing. Repeated staged debridement and lavage may be necessary at each bandage change (generally q24hours for the first 1-3 days then q48hrs)

2. ***The Reparative stage***

The aim during the reparative stage is to form and maintain healthy granulation tissue and to achieve rapid contraction and epithelialisation

Role of primary bandage layer:

- ⇒ Maintain moist wound environment
- ⇒ Protect wound
- ⇒ Prevent infection/inflammation
- ⇒ Facilitate epithelialisation
- ⇒ Facilitate wound contraction

Primary layer options for **late inflammatory/early reparative stage** (Figure 2)

- ⇒ ?Wet-to-Dry dressing – **but** will lead to continued indiscriminate mechanical debridement which will slow cell proliferation, so in general not a good choice after 48hours.
- ⇒ Moisture retentive dressings
    - Polyurethane foam dressing
    - Hydrogels (+ either a non-adherent dressing or a foam dressing)
    - Alginate dressings (+ either a non-adherent or a foam dressing)
- ⇒ Medical-grade Honey (+ non-adherent/foam dressing to maintain in place). Very useful if concerns that the wound is becoming infected. Once there is good granulation tissue formation this should no longer be necessary
- ⇒ Negative Pressure Wound Therapy – again only really for large exudative wounds or those in difficult to bandage areas.

Primary layer options for **reparative stage** <u>once there is good granulation tissue</u>

⇒ Moisture retentive dressings
  - Polyurethane foam dressing/Highly absorptive dressing
  - + Hydrogel if drying out

Primary layer options for **late reparative/maturation stage**

⇒ Non-adherent dressing – to protect fragile epithelial surface while it matures

⇒ Polyurethane foam dressing – if still small area left to epithelialize, this can keep the area slightly moist.

⇒ These bandages may only need to be changed every 4-6 days depending on the location of the wound and the amount of exudate.

Further reading

BSAVA Manual of Canine and Feline Wound Management and Reconstruction, 2nd Edition, 2009, BSAVA

Atlas of Small Animal Reconstructive Surgery 3nd Edn., Pavletic M.M., W.B Saunders

Textbook of Small Animal Surgery, 3rd Edn, Slatter, W.B. Saunders

Veterinary Surgery: Small Animal, Ed. Tobias & Johnson, Elsevier

Veterinary Clinics of North America, Small Animal Practice: *Wound Management,* July 2006, Ed Swaim S.F., Krahwinkel D.J.