STS2

Making Ends Meet: 
Wound Management and Closure
in Dogs and Cats

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Understanding the Process of Wound Healing

Wound management is a field, which has undergone considerable advances in the last 20 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 Similarly wound management dependent on outdated theories or therapies will often be to the detriment of the wound.

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 the most successful for the vast majority of wounds encountered.

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 panniculus 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 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.
Stages of Wound Healing

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.

1. Haemorrhage/Coagulation/Initiation
2. Inflammation and Debridement
3. Reparative
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 the stages.

1. Haemorrhage/coagulation/initiation

Trauma to tissue results in disruption to blood vessels and cell membranes. Obviously the type and degree of trauma sustained is important in determining the subsequent progression of wound healing. The immediate haemorrhage flushes the wound surface and fills the wound. Vasoconstriction of the vessels occurs rapidly to reduce blood loss but this lasts only about 5-10 minutes. After this the vessel undergo vasodilation allowing extravasation of intravascular cells and fluid into the extravascular space. The blood clot that forms due to the activation of platelets and the crosslinking of fibrin 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 (minimal) wound strength. The surface of the clot dries to from a scab under which wound healing may progress with some protection.

2. Inflammation and Debridement

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 neutrophils phagocytise bacteria and extracellular debris as well as release superoxide radicals that kill bacteria and degrade debris.
Neutrophils also release chemoattractants for further neutrophils. The combination of debris, extracellular fluid and dead neutrophils makes up the wound exudate visible at this stage (pus). Monocytes also migrate into the wound along with the neutrophils but as they make up a smaller percentage of the leukocytes within the blood they are initially in small numbers. With time they begin to predominate, as the neutrophils are short lived. 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, depleted neutrophils. Macrophages control the wound environment by cytokines that modulate the wound from the inflammatory to the proliferation phase with the formation of granulation tissue. If there is continued foreign material/infection within the wound (chronic inflammation) then proliferation of monocytes occurs and the development of granulation tissue can be delayed or hindered.

**Macrophages are essential to wound healing – initially they effectively debride the wound and then modulate 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 proliferative 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 has been apposed and there has been minimal trauma, devitalised tissue or infection (as with a surgical wound), the inflammatory phase is minimal and the wound may begin to epithelialise at this stage.

3. Reparative

This stage is characterised by the formation of granulation tissue and epithelialisation. In the later stages of the stage wound contraction occurs.

**Granulation tissue formation**

This 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 under the control of mediators from the provisional ECM and macrophages. Fibroblast migration into the wound is along the ECM molecules and fibrin strands. Wound
fibroblasts do not survive in adverse environmental conditions. Their high metabolic rate creates a requirement for oxygen and they do not compete well with bacteria. With fibroplasia there is the simultaneous process of angiogenesis to supply these requirements. Endothelial cells initially migrate and then proliferate within the ECM to form capillaries. This ingrowth of capillaries is from the surrounding pre-existing vessels at the wound edges and again modulated by wound macrophages. The rate of capillary in-growth is therefore dependent on the vascularity of the surrounding tissue, which is why wounds over muscle will rapidly form granulation tissue whereas those over bone and tendon will not. Migrating capillary buds advance from surrounding tissue into clean wound @ 0.4-1.0mm/day.

The wound fibroblasts produce collagen and ground substance within the wound which leads to the transformation of the provisional ECM to the true collagenous ECM. Collagen confers strength to the wound changing it from weak fibrin-based ECM to more durable granulation tissue.

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. Remember however that the rate of development will vary depending on the degree of inflammation/infection present and the surrounding tissue type (bone, tendon sheaths, periosteum, fascia, nerve sheaths produce more slowly). In larger wounds there may be areas of the wound that are still in an inflammatory/debridement stage whereas the rest will be in the reparative stage.

Normal healthy granulation tissue very pink, granular and slightly moist in appearance. Pale, dry granulation has poorer vascularity and therefore poorer collagen synthesis. This is likely to lead to significant delays in healing.

**Recognition of granulation tissue is key to identifying the reparative stage of wound healing**

**Granulation tissue develops from the wound margins therefore careful handling of the margins of a fresh wound or surgical wound is essential to prevent delays in healing**

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. Matrix metalloproteinases are enzymes produced by the fibroblasts, epidermal cells and macrophages to remove damaged
ECM and to reorganise the wound. Their behaviour is thought to be modulated by the macrophages, however their action can be indiscriminate leading to destruction of the wound. In inflamed wounds their destructive action will prevent initiation and progression of the reparative phase. Therefore prevention of inflammation during the reparative stage is essential for wound progression. Also as wound exudates contain high levels of these enzymes control of exudate is very important during this stage of wound healing.

**Contraction**

Contraction depends on adherence of the skin edges to the underlying granulation tissue as the edges are actively moved over the wound. Visible wound contraction is evident by 5 to 9 days after injury but obviously depends on a good granulation tissue bed (with active myofibroblasts). As animals generally have very abundant and elastic skin, the degree of contraction that can occur is generally very significant. This can be anticipated by assessing the degree elasticity of the surrounding skin. Contraction can also be aided by stretching the surrounding skin. Contraction can be undesirable if this will limit mobility (especially if it occurs on the flexor surface of a joint) or if it will lead to uncosmetic scar (especially seen with large circular defects). Contraction decreases as the wound progresses due to a drop in the number of myofibroblasts. Contraction ceases when the wound edges are apposed or when the tension in the surrounding tissues overcomes the strength of contraction.

**Epithelialisation**

Epithelialisation is the other key event that is occurring during the reparative stage. In the very early phases of a wound there is migration of epithelial cells from the peripherary of the wound. In a closed sutured wound can be covered with epithelium within 24-48 hours whereas with an open wound epithelialisation may not be noted until 4-5 days after injury. With partial thickness abrasions epithelial cells will migrate from the adnexal structures (such as sweat glands and hairfollicles) and rapidly re-epithelialise a wound.

| 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 migrate over each other onto the wound surface where they then attach and start to undergo replication. The new epithelial cells then migrate again. This leapfrogging of cells over each other continues 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. The basement layer of cells continues to undergo replication until a stratified layer of cells develops and further differentiation occurs to develop a keratinised surface. Macroscopically the epithelial surface changes from a pink appearance, due to the vascularity of the underlying granulation tissue, to a pale colour as it thickens and the granulation tissue vascularity decreases. 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. In full thickness wounds the adnexal structures do not regenerate.

4. Maturation
Even though an open wound may be considered closed once there is a covering of adequate epithelium, considerable healing still needs to occur as the wound matures. The initial random and haphazard arrangement of the collagen and cellular content of the granulation tissue needs to undergo considerable reorganisation. 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. Maximal strength occurs when the collagen fibres are orientated parallel to the lines of greatest stress. This process occurs with increased use of the injured animal. Collagen fibres that are inappropriately orientated are removed. Even with this maximal strength after the end of maturation, which may take months to years, is usually no more than 80% of normal.

Promoting early but protected use of a wounded area encourages alignment of fibroblasts and collagen along anticipated lines of physiological stress. Physiotherapy and massage are therefore important in the rehabilitation process.

Wound strength of the healing wound:
Initial wound strength is provided by the fibrin clot for the first 3-5 days. The ingrowth of capillaries and of any epithelialisation across an apposed will provide some wound strength. The most rapid increase in wound strength occurs between 7 and 14 days as there is a rapid accumulation of collagen within the wound. However wound strength by 3 weeks after injury is only about 20% of their final strength. Further increases in strength occurs slowly over months to years but even at maximal strength is no more than about 80% as strong as normal tissue.
Principles of Wound 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 as possible to allow a rapid return to function. This will be achieved most rapidly with primary closure of a wound. However if there is significant contamination, devitalisation or infection, then inappropriate primary closure can lead to major wound complications. Therefore in many cases a period of initial open wound management is required. This allows continued evaluation, drainage and debridement of the wound. This can then be followed by delayed primary closure, once the inflammatory stage has subsided. More commonly there will be a delay until there is the presence of granulation tissue/epithelialisation (the reparative stage), at which closure at this stage is called secondary closure. Ongoing open wound management will allow the wound to eventually close by second intention healing, however this can be time-consuming and expensive. If there is extensive scarring that is poorly functional or uncosmetic then revision surgery of the site may be required.

In order to achieve rapid healing of the wound with minimal disruption in function, minimal inconvenience to the patient and minimal cost to the client, an active decision making approach to wound management is required. This is needed at every stage of wound management, but in particular when initially assessing and managing the wound. Obviously management of the whole animal is more important that managing just 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. An example is the extensively damaged dog or cat following a major trauma which may be in shock and is at risk of developing systemic inflammatory response syndrome and disseminated intravascular coagulation.

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 (they become unnecessary when there is a healthy
granulation tissue bed within the wound). Good analgesia is also essential to improve comfort and decrease stress. Wound assessment is then performed under sedation or general anaesthesia once the animal is reasonable stable.

Acute wound management

1. Initial wound evaluation
2. Debridement and lavage
3. Further evaluation and decision to close or manage open

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:** partial thickness skin wounds where there is loss of the dermis and portions of the dermis. These wounds generally rapidly re-epithelialise but need protection to prevent further damage or contamination. A severe form of abrasion injury is that seen to the lower limbs with shearing injuries following road traffic accidents. This type of injury can be very challenging due to the extensive tissue that is lost along with the major orthopaedic injuries that can occur (tendon/ligament and bone loss). Closure options for wounds in this area can be difficult often requiring skin grafts or axial pattern flaps.

**Avulsion:** skin is torn from its underlying attachments. These are common with the distal limbs (the degloving injury). The skin that is detached is dependent on the blood supply from the subdermal plexus arising from the flap’s base. If the degree of underrunning is limited, these flaps may be excised or managed until there is an underlying granulation bed to suture them to. However if extensive then preservation by early management of contamination, resuturing to the underlying attachments and management of dead space is necessary. Even with
this approach major portions of the flap may undergo necrosis due to vascular damage.

**Incision:** as seen with surgical wounds. Wound edges are smooth and there is minimal trauma to surrounding tissue. Immediate primary closure of this type of wound is usually possible with little risk of dehiscence.

**Laceration:** these are ragged incisions with variable damage to the underlying and surrounding tissue. The skin edges are often detached from their underlying fascia and there may be vascular compromise extending beyond the wound margins. This type of wound can generally be closed primarily but may require more extensive debridement with careful assessment of the viability of the wound edges and dead space is required. In some cases an en-bloc debridement will allow removal of all of the wound bed and conversion to a clean incision.

**Burns:** these are classified according to their depth being either first degree (superficial), second degree (partial thickness) or third degree (full thickness). Second and third degree burns are more serious due to their extent and their potential life-threatening nature from the development of shock and systemic derangement. Secondary infection of the burn site is also common. Emergency care is aimed at cooling the area with towels soaked in ice-cold water or submersion in cold water. This helps to limit pain and possibly the progression of the burn.

Following stabilisation the extent of the burn can be assessed. For superficial and partial thickness burns the area is managed to maintain a moist wound surface, necrotic tissue is removed and reepithelialisation occurs from the surviving adnexal structures. If the area easily excised and reconstructed this may allow the quickest and most cosmetic resolution of the area. For full thickness burns, the definitely devitalised area (known as the burn eschar) is excised and the wound is managed either by definitive closure or open wound management. Questionable areas of viability can be covered with a topical antibiotic ointment – silver sulfadiazine (*Flamazine*) ointment is particularly suited to this due to its deep penetration of the eschar and effectiveness against a broad spectrum of bacteria. Eschar retention has been shown to slow granulation tissue formation, contraction and is a medium for bacterial proliferation.

**Puncture:** these are most commonly due to bite wounds but can also be with ballistic missiles. Puncture wounds can be very misleading as although there
may be minimal external skin damage there may be extensive damage to the underlying tissue with contamination with hair, debris, bacteria etc. Due to the lack of drainage, a closed hypoxic area develops which is an ideal environment for bacterial growth. Often cellulitis or abscessation can develop in these areas, sometimes leading to major systemic derangement. Many of these wounds can also have deep retained foreign bodies.

Bite wounds should always be treated seriously and surgical exploration, debridement, copious lavage and management of dead space is indicated. Due to the major risk of infection, broad spectrum antibiotics are indicated. Deep tissue biopsies for culture are necessary with deep contamination.

Thoracic and abdominal wall puncture wounds need to be managed with caution due to the possibility of major thoracic and abdominal injuries. Careful monitoring and aggressive intervention may be required if there is a failure to respond to stabilisation.

Obviously the position of the wound is also important, both from the proximity of important local structures and the effect that the wound is having on local and systemic function.

b. Evidence of contamination/infection

Open wounds can be classified by the degree of contamination as either clean (none), clean-contaminated (minor contamination), contaminated or infected (when there is greater than $10^5$ bacteria/gram of tissue). Bacteria become detrimental to a wound when they overcome the wound defences due to their numbers or virulence. The bacteria occupy the macrophages preventing progression to the reparative stage, but also produce enzymes that breakdown fibrin and collagen.

The presence of foreign bodies, necrotic and devitalised tissue in contaminated wounds decrease the number of bacteria required to overcome the immune defences and lead to infection developing. The development of a seroma or the presence of haematoma similarly increases the risk of infection. Therefore appreciation of the need of adequate drainage of a wound is important.

Using specific time periods since the injury (such as the 6 hour ‘golden period’) to determine infection is generally unhelpful as the wound condition is more likely to be associated with the type of contamination, the degree of traumatised tissue present and the vascularity of the surrounding tissue.
Culture of infected wounds is best achieved by taking a biopsy of tissue within the wound bed rather than a superficial swab. This should identify the pathogenic bacteria and not just surface contaminants. As healthy granulation tissue is highly resistant to infection, culture of surface exudate is of little value. If there is a major deterioration of granulation tissue then a biopsy can be valuable to identify infection.

c. Adequacy of blood supply
Assessing the adequacy of the local blood supply is important as the development of granulation tissue is from the adjacent tissue. With poorly vascularised tissue the development of granulation tissue will be slow. The ability of the immune system to access the area may also be more limited, increasing the risk of infection. Assessing the vascularity of the wound bed or avulsed skin flaps can be difficult in the early stages but is important when deciding on the extent of debridement necessary (see later).

d. Stage of healing
Not all wounds present in an acute stage or have a clear history. Repeated assessment of most wounds is also necessary. Therefore being able to assess the stage of wound healing is critical in decision making. Assessing if the wound is progressing as expected or not is essential in the early recognition of the difficult non-healing wound. Knowledge of the events occurring during each stage is also essential (see previous chapter) in deciding on the most appropriate wound dressing for a wound (see later).

2. Debridement and Lavage
Devitalised tissue, foreign bodies and bacteria prolong the inflammatory phase and promote infection. Removal of this material therefore helps to minimise this phase and speeds the development of 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 |

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In preparation for this the animal is usually under general anaesthesia. The open wound is covered with sterile K-Y jelly or moistened saline swabs prior to a wide clip of the surrounding hair. Hair at the wound edge can be removed using a scissors with the blade edges smeared with K-Y jelly. Dirt and debris surrounding the wound edges removed with antiseptic scrubs of either chlorhexidine gluconate or povidone iodine with care to avoid contacting the open wound. A water-impermeable drape is draped around the wound site.

a. Debridement

The extent of debridement will depend on the degree of trauma and contamination of the wound. Minimal debridement followed by closure may be possible for clean or minimally contaminated wounds. Before debridement the wound is carefully explored to assess the depth, degree of contamination and vascularity. Haemorrhage from a tissue is generally a good indicator of viability, although with some tissues especially skin), the lack of haemorrhage does not denote devitalisation. Similarly with vital structures (such as nerves and tendons) a decision on viability is probably best delayed. Therefore the most common technique for debridement is a staged layered approach – where the debridement begins on the surface and progresses to the deeper layers with questionable tissue left for debridement at a later stage. Staged debridement allows questionable tissue to be preserved or to become obviously necrotic (particularly with skin). This may be especially important where the tissue will be required for tension – free closure

Debridement can be performed as a single event with complete excision of the wound bed, thereby converting it to a clean wound. This is followed by wound closure and provision of adequate drainage. This is obviously only applicable in areas where sufficient tissue allow.
Other methods of debridement include enzymatic and mechanical. Enzymatic debridement is of limited application and expensive. Medicinal maggots secrete enzymes onto the wound that selectively dissolve necrotic tissue, disinfect the wound and appear to stimulate granulation tissue. The most useful and commonly used technique is the use of wet-to-dry bandages for ongoing mechanical wound debridement after surgical debridement (see later).

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, aims to create ideal conditions for autolytic debridement. This is important from 24 hours after injury and attempts should be made to limit disruption of this.

### Rules of debridement

- Sharp excision with a scalpel is generally best
- Be conservative with skin
- Preserve bone, tendon, blood vessels and nerve
- Be radical with fat, muscle, haematoma
- Use clinical judgement – there is no point in preserving obviously necrotic tissue

**b. Lavage**

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 initially to mechanical remove this material to allow clearer evaluation of the wound. It is then used after each layer of debridement and at the end of the process. For open wound management gentle lavage is a routine step to remove excess wound exudates and devitalised cells.

Most small to moderate sized wounds are lavaged with 500-1000ml of an isotonic solution. Larger more extensive wounds require a larger volume. Some pressure is required to remove bacteria and 8 pounds/sq inch appears to be maximally effective. I achieve an approximation of this with a 20 or 50ml syringe with an 18G needle. For ease...
of use I attach these to a bag of isotonic fluids, a giving set and a three way tap. High pressure lavage (> 25psi) holds no major advantage and leads to oedema of the deeper tissues that increases the risk of infection.

**Types of lavage fluid:**

*Tap water:* In the early stages of a grossly contaminated wound use of tap water is possible. Being very cheap large volumes can be easily used. However it is hypotonic this is potentially toxic to the inflammatory cells. It is therefore best to use it for no more than the first 24 hours (or not at all) and not if there is evidence of granulation tissue formation.

*Isotonic solutions:* Normal (0.9%) saline or Hartmanns (Lactated Ringers) solution are the most useful solutions for the lavage of wounds. They are isotonic, sterile, easily available, relatively cheap and minimally toxic to the wound tissue. Of these two solutions, Hartmanns may be marginally less cytotoxic although normal saline does not appear to impede wound healing.

*Antiseptic solutions:* Topical antiseptics are toxic to fibroblasts and epithelial cells and probably do more to slow healing than to counter infection. They are also rapidly diluted by wound exudates. Chlorhexidine diacetate (Hibitane diacetate) diluted to a 0.05% solution in water significantly reduces bacteria on wounds without increasing tissue inflammation. This also has a residual activity and is active with residual organic material. Some gram negative organisms, such as *Pseudomonas*, can develop resistance to it. An alternative is povidone-iodine (Pevidine) diluted to a 1% solution in saline, which has good antimicrobial activity but is inactivated by organic material and has no residual tissue.

Other solutions that are used include Dakins solution (0.25% sodium hypochlorite (bleach)) but this is not recommended for routine use. Hydrogen peroxide is not recommended as it is of little value as an antiseptic but can cause considerable tissue damage. Tris-EDTA has antibacterial properties especially against many gram negative bacteria (especially *Pseudomonas, Proteus and E.coli*). It can therefore be very useful for difficult topical infections. Its effect is to damage the cell wall and can be used synergistically with other antimicrobials.

**The default lavage solution is always either sterile saline or Hartmanns solution**
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 (see later).

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 techniques for wound closure are detailed in a later section.

The decision regarding ongoing wound management has major implications from the point of view of the work involved for veterinarian, 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. This plan should be aiming to actively manage the wound so as to achieve resolution in the shortest time with the least cost to both animal and client. 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. In many cases the ‘big’ reconstructive surgical option will achieve the quickest and cheapest resolution. 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. For referral the wound is bandaged to prevent damage during transport.

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.

Effective debridement and lavage with saline/Hartmanns is always preferable to lavage with antiseptics
The treatment plan may change and must react to changes within the wound; therefore ongoing ACTIVE evaluation is essential for effective wound management.

‘Active’ Wound Management

1. Wound Closure Possible

Options
- Primary closure
- Advancement/Rotational flaps
- Axial Pattern Flap

Plan
- Surgical debridement
- Prompt closure by chosen method once contamination/infection controlled

2. Wound Closure Impossible

Options
- Free skin graft
- Open wound management and contraction/epithelialisation

Plan
- Proactive open wound management to achieve excellent granulation tissue bed at 3-5 days
Ongoing Open Wound Management

The objectives with ongoing open wound management are to:

1. Minimise the inflammatory/debridement stage and promote the development of the reparative stage
2. Manage the reparative stage to encourage contraction and epithelialisation

The wound is managed by ongoing assessment and appropriate bandage selection

At each bandage change the following needs to be assessed:

- **Degree of inflammation**
  - ongoing or increased inflammation prevents the development of the reparative stage of wound healing
  - Intervention is needed at each bandage change or with the primary dressing to debride the foreign or necrotic material

- **Degree of exudate**
  - the inflammatory and reparative stages of wound healing are enhanced in a warm, moist environment. This is the concept of MOIST WOUND HEALING. The functions of cells, proteases, and growth factors are supported by maintaining this environment using a moisture retentive dressing (MRD). Wound exudate provides the appropriate ratio of proteases, protease inhibitors, growth factors and cytokines at each stage of wound healing.
  - Excess wound exudates needs to be removed as it can contain excessive proteases (especially in chronic wounds) that can damage the wound by increasing inflammation. It can also lead to maceration of the surrounding skin edges.
  - The aim is to keep the wound bathed in exudates but not drenched in them

- **Presence and quality of granulation tissue**
  - the presence of granulation tissue is indicative of 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. If there is chronic granulation tissue then intervention is needed to either debride and kickstart the process or restimulate activity in the granulation tissue bed.

**An essential wound management skill is the** identification and monitoring of the growth and quality of granulation tissue.

- **Skin edges**
  - adherence of the wound edges to the underlying fascia or granulation tissue is essential for contraction and epithelialisation to occur.
  - Avoid the development of large underrun pockets lined with thin chronic granulation tissue. This is particularly seen in cats and in high motion areas such as the axilla and inguinal region.

- **Degree of epithelialisation**
  - epithelialisation needs a smooth granulation bed with well adhered wound edges to proceed. 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 assist the wound healing process. 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 (e.g. Soffban) or cotton wool. The final tertiary layer is to secure and compress the secondary layer. This is usually a nonadhesive conformable bandage (e.g. K-lite, Easifix) followed by an adhesive outer layer (e.g. Vetwrap, Coflex). Correct bandage construction is a skill not to be underestimated.

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 (e.g. Surgifix), 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 discussion 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. Most of
the bandages have been designed with the human patient in mind and although they
may speed up wound healing marginally, they often do not justify the expense involved.
The objective in dogs and cats is to promote normal healing to progress and avoid
dressings that are likely to hinder the process. Again an ACTIVE decision making
approach is necessary rather than falling into default mode but as a general rule - KEEP
IT SIMPLE!

Primary Contact Layer Options:

*Wet-to-Dry dressings:*
- Heavily soiled or necrotic wounds only
- Sterile gauze, soaked in saline applied directly to wound surface
- Bandaged in place with secondary absorptive layers
- Changed every 12-24 hours depending on wound status (degree of exudate)
- Dead tissue and debris wicks into the dressing as it dries and is 'lifted' off wound at
  change. Sedation and analgesia is necessary at bandage change due to discomfort
- This is a highly effective and cheap dressing
- The mechanical debridement that occurs is indiscriminate and I usually discontinue
  its use after 24-48 hours

*Moisture retentive dressings:*

*Foam dressings:* Polyurethane foam (e.g. Allevyn, Advazorb Plus)
  - The primary function is absorption and will function in minimally to heavily exudative
    wounds at all stages of wound healing.
  - They absorb excess moisture and keep the wound surface moist, thereby promoting
    autolytic debridement, granulation tissue formation, contraction and epithelialisation
  - They have no bioactivity and no mechanical debriding action
  - They can absorb up to 10 times their own weight and therefore do not need to be
    changed as frequently for moderately exudative wounds in the reparative stage.
  - There is a tendency to dry the wound due to the semi-permeable backing on the
    dressings and therefore require some exudation from the wound to maintain a moist
    wound environment.
**Highly absorptive dressings**  Example: Eclypse, Eclypse Adherent

- Highly absorptive primary wound dressings have a high capacity for wound exudate, therefore are very useful for the highly exudative wound, thereby preventing maceration of the tissues.
- Another example if reduced cost is required is using a nappy, which are designed to be highly absorptive, although this is probably best as a secondary layer.

**Hydrocolloid dressings**: Examples: TegasorbTM, GranuflexTM, Cutinova Hydro

- These dressings are bioactive, encouraging the growth of granulation tissue but also allowing good debridement of the wound.
- They create an excellent moist wound environment and once it forms a gel it is non-adherent.
- They are however expensive, the wounds may initially enlarge, may require frequent changes as they are less absorptive and they are not suitable for infected wounds

**Hydrogels**: Examples: Citrugel, Intrasite, NuGel

- Hydrogels keep the wound surface moist, facilitating autolytic debridement and rehydrating necrotic tissue.
- They are highly absorptive thereby reducing oedema,
- They are useful on minimal to low exudates wounds to keep them moist
- They need a secondary dressing to maintain in place – vapour permeable film or foam dressing
- Anaerbes can also grow in the gel.

**Alginate dressings**: Examples: Kaltostat, Algivon (including honey)

- Calcium alginate dressings actively encourage the formation of granulation tissue and maintain a moist wound environment
- They can therefore be useful in moving the wound from the inflammatory to the reparative stage
- They can be used in infected wounds (especially if contain honey)
- Disadvantages are the potential over-stimulation of granulation tissue and they generally require a secondary dressing to maintain them (such as a polyurethane foam) and remove excessive exudate
Honey/Sugar:

- Honey (Examples: Activon Tube, Activon Tulle (dressing), Algivon (alginate impregnated with honey))
  - Honey is antibacterial due to low levels of hydrogen peroxide, hypertonicity, low pH and inhibins.
  - The hypertonicity aids debridement and removes excess exudate/oedema. The wound surface is kept moist, thereby aiding wound healing.
  - It also promotes the rapid formation of granulation tissue.
  - Sterile honey must be used to avoid contamination with clostridial spores and Bacillus spp.

- Sugar paste
  - Can be used on dirty and infected wounds due to its antibacterial effects. It acts by competing for the freely available water with bacteria. It also reduces oedema. It is not suitable for granulating wounds.

Non-adherent/low adherence dressings:

- Perforated polyurethane membranes dressings backed with variable amounts of absorptive material (e.g. Melolin, Rondopad, Primapore etc).
  - These are primarily used on closed wounds to prevent contamination over the first 12 hours and to prevent adherence of secondary bandage material.
  - They can also be used to protect fragile epithelium on wounds in the maturation stage of wound healing.
  - These dressings have a slight drying effect as they are fully permeable and are therefore generally not indicated for an open wound. They are also used to maintain other wound dressings such as hydrogels and honey, but will need to be changed frequently due to their drying effect.

- Silicone surface (Silflex)
  - These are almost completely non-adherent. Allows one way movement of exudate to secondary absorptive layers. They do not tend to interfere with normal healing and are therefore useful for delicate epithelialising wounds or skin grafts.

- Paraffin gauze (e.g Jelonet)
  - This is cloth material impregnated with soft paraffin. The paraffin stops the secondary dressing sticking to the wound.
Exudate is absorbed by the secondary layer so there is a major drying effect. The dressing can dry onto the surface of the wound. This type of dressing now has very limited application with the modern moist wound environment approach to wound healing. This dressing also slows epithelialisation.

**Biologic dressings:**
- Collagens (e.g. Biosist, Collamend, Emovet)
  - Action is questioned – may improve epithelialisation but may delay contraction.
  - Possibly acts as scaffold for fibroplasia as becomes incorporated into ECM of wound and may also act as a stem cell attractant into wound

**Maggots:**
- Medicinal maggots available through website [www.LarvE.co.uk](http://www.LarvE.co.uk)
  - Larvae of *Lucillus sericata* produced in sterile manner.
  - Maggots used since antiquity. Stage 1 larvae lack mouthparts and act by secreting digestive enzymes onto wound selectively dissolving necrotic tissue, bacteria and exudate.
  - Left in place for 3 days, but must be kept hydrated. Then removed and new batch can be applied.
  - Rarely indicated for only specific wounds that are not amenable to surgical debridement/standard debriding dressings. Often by time maggots have been ordered and delivered, the wound is out of a dirty/infected state!
  - May be useful at promoting granulation tissue.

**Vacuum-Assisted Closure**
- Wound management systems available from KCL (*VAC™*) and Smith&Nephew
  - A layer of special foam is applied to the wound, with interstices that allow transmission of negative pressure through to the wound bed.
  - A tube is inserted under an occlusive outer layer and attached to an external device that generates a negative pressure. This device sucks exudate away from the wound bed. It also applies inward traction on the wound edges, encouraging wound contraction and stretching of the surrounding skin.
o This type of dressing can be applied to virtually any wound, including wounds in areas that would traditionally be very difficult to bandage as the vacuum applied holds the dressing onto the wound site as long as it is kept air-tight. Once applied, the dressing need only be replaced when the fluid reservoir fills with fluid, or the clinician wishes to inspect the wound (usually every 2-3 days). This is an effective way of debriding open wounds as necrotic tissue is sucked away as soon as it liquefies.
o Anecdotal reports suggest that open wounds treated with vacuum assisted closure granulate and contract more quickly than wounds treated with conventional bandaging.

Polyurethane foam dressings are an excellent dressing during most stages of wound management as they are applicable to minimally to heavily exudative wound. They absorb excess moisture and keep the wound surface moist, thereby promoting autolytic debridement, granulation tissue formation, contraction and epithelialisation.

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 – mechanical debridement – I rarely use this for longer than 48 hours on the wound, as after this it is too destructive to the wound and delays onset of the reparative stage. After this dressing I switch to a moisture retentive dressing.
⇒ Moisture retentive dressings – autolytic debridement
• Polyurethane foam dressing (e.g. Advazorb, Allevyn)
• High absorptive capacity bandage (e.g. Eclypse)
• Hydrogels (e.g. Citrugel, Intrasite, NuGel etc) (+ either a non-adherent dressing (e.g. Melolin) or a foam dressing)
• Alginate dressings (e.g. Kaltostat) (+ either a non-adherent or a foam dressing)
⇒ Honey (+ a dressing to maintain in place) - autolytic debridement and antibacterial effect. This is probably my dressing of choice in an infected/heavily contaminated wound environment
⇒ Vacuum assisted closure
⇒ ?Maggots

Frequent bandage changes are necessary to remove exudates and prevent water logging of dressing. Repeated staged debridement and lavage may be necessary at each bandage change.

2. The Reparative stage
The aim during the reparative stage is 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
⇒ ?Wet-to-Dry dressing – but will lead to continued indiscriminate mechanical debridement which will slow cell proliferation
⇒ Moisture retentive dressings
  ▪ Polyurethane foam dressing (e.g. Allevyn, Advazorb)
  ▪ Hydrogels (e.g. Intrasite, NuGel etc) (+ either a non-adherent dressing (e.g. Melolin) or a foam dressing)
- Alginate dressings (e.g. Kaltostat) (+ either a non-adherent or a foam dressing)
  ⇒ Honey (+ non-adherent/foam dressing to maintain in place). Very useful if concerns that the wound is becoming infected
  ⇒ Vacuum assisted closure

Primary layer options for **reparative stage** once there is good granulation tissue
  ⇒ Moisture retentive dressings
    • Polyurethane foam dressing/Highly absorptive dressing
    • + Hydrogel if drying out
    • Vacuum assisted closure

Primary layer options for **late reparative/maturation stage**
  ⇒ Non-adherent dressing – to protect fragile epithelial surface
  ⇒ Polyurethane foam dressing – if still small area left to epithelialise this keeps the area moist.

Encouraging contraction to occur can be achieved by placing sutures from the wound edges across the wound, only if the edges are attached to the underlying granulation tissue. These can be gradually tightened every 2-4 days to help bring the edges together. Vacuum assisted closure is another option currently gaining popularity.

**Perform ACTIVE bandage management by assessing at each change:**

- **Degree of inflammation**
- **Presence and quality of granulation tissue**
- **Degree of exudate**
- **Skin edges**
- **Degree of epithelialisation**
Principles of Surgical Oncology

Treatment of the cancer patient requires an informed decision on the part of the owner and the veterinarian. Questions that may be helpful include identity of the cancer, expected biological behaviour of the tumour (benign vs malignant, local invasion vs metastasis and expected sites of metastasis), options for treatment (surgical vs medical), welfare of the patient before, during and after treatment, prognosis with, and without, treatments and cost of treatment.

Assessing the mass

The following observations should be recorded about a mass:

- Location – ideally use a body map to record the location
- Description of the mass – appearance, attachment to skin, muscle etc. diffuse vs circumscribed
- Size of the mass – measure with callipers

The identity of the mass should then be elucidated.

All suspicious dermal and subcutaneous masses identified at routine examination (e.g. vaccination) should ideally be subjected to a fine needle aspiration.

Cytologic evaluation of the mass

Cells can be collected from tumours by a variety of techniques:

- Fine needle aspiration (FNA)
  - Diagnostic cytology is easy, quick and cheap and can be used to obtain information about a wide variety of masses and body fluids. Superficial masses can be easily immobilised and are readily sampled. Deeper masses within the body cavity may be aspirated under ultrasound guidance.
Multiple samples are taken from the mass at different sites if possible. In larger masses try to avoid sampling only the centre of the mass as the centre is often necrotic and therefore not representative of the mass.

- Impression smears from surface of tumour
- Tissue scrapings from surface of tumour

**Biopsy**

Cytology does not reveal architectural information about a tissue. In addition, certain neoplasms may not exfoliate sufficient cells for a cytologic diagnosis or cytologic examination may provide insufficient information to make an accurate diagnosis. Histopathologic examination is necessary for assessment of tissue architecture and may be used to establish the tumour grade (e.g., for mast cell tumours) which may affect prognosis and, consequently, the treatment.

There are a variety of techniques for collection of tumour samples for histopathology:

- Needle biopsy (e.g., Tru-cut and Jamshidi)
- Biopsy forceps used for sampling tumours during endoscopy
- Incisional biopsy (including skin-punch biopsy)
- Excisional biopsy

**Needle biopsy** is a very commonly used biopsy technique, which is especially useful for biopsy of abdominal organs (liver, spleen and kidney) with ultrasound guidance. It is a straight-forward and quick method of getting a sample, but has the disadvantage that the sample size is small. This can be a problem if the sample collected is not representative of the tumour (for example, an area of haemorrhage or necrosis) and is non-diagnostic. Biopsy forceps are crocodile jaw type ‘grab’ forceps that are used to take samples from the mucosal surface of the respiratory, gastrointestinal and urinary tracts generally using endoscopy for guidance.

**Incisional biopsy** is generally applied to tumours which can be approached for direct visualisation but which are too large to be easily or completely removed, particularly where the histopathology may alter the treatment plan, for example tumours on distal limbs.
A wedge or a core is taken from the tumour in an area that could later be completely excised. The section should be large enough and deep enough to obtain a representative sample and ideally should contain a junction between normal and abnormal tissue. Avoid biopsy of an area that contains only ulcerated or inflamed tissue as this may provide a non representative sample. Incisional biopsy is usually easily performed under sedation/local or short GA

| Incisional biopsy is an oft neglected technique but is ESSENTIAL with tumours that might require major surgical intervention. The information provided may strongly influence the planned surgery, especially as the ‘the first time to cut is the best time to cure’. Newer histopathologic assessment (such as Ki-67 for mast cell) tumours can significantly affect the approach to management |

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**Excisional biopsy** is suitable for small or easily removed tumours (for example dermal tumours on the trunk). Diagnosis and treatment are therefore performed concurrently. Preoperative assessment of the tumour via cytology is preferable to ensure adequate margins are obtained to maximise probability of a cure. As the subsequent scar may be larger than the original mass, it is important that consideration is given to the complexity involved if subsequent scar excision if tumour remains is then necessary.

**Surgical Treatment of Cancer**

Despite the advances in chemotherapy and other treatment modalities, surgery continues to be the most effective option for the management of cancer. Clinical cures are more commonly attained by surgical extirpation of localised disease than with any other treatment modality, however ‘the first time to cut is the best time to cure’ and subsequent surgeries following an incomplete resection are more likely to be associated with tumour recurrence.

Before the tumour is removed, the surgeon must consider the ‘dose’ of surgical intervention required, i.e. is local excision sufficient or is enbloc or compartmental excision necessary.

Preoperative assessment must include assessment of the patient for concurrent disease. Some tumours can cause specific clinical disease (paraneoplastic disease) that can
complicate case management. If the tumour is considered malignant, accurate staging of the tumour is essential to provide an accurate prognosis. This requires examination of local and regional lymph nodes and determination of distant metastasis via a combination of imaging modalities.

Surgical management of cancer should ideally be performed with curative intent. Important features of oncologic surgery include:

- Minimal and gentle handling of neoplastic tissue to avoid exfoliation of tumour cells during the surgery
- Irrigate the wound with sterile saline following extirpation to remove any exfoliated cells
- If the tumour has been biopsied remove the biopsy tract
- Handle and cut through normal tissue not the tumour.
- Ligate the venous drainage for large encapsulated tumours early in the procedure to avoid haematogenenous spread of large tumour emboli.
  - *This is open to question as it this will lead to a blood engorged mass until the arterial supply is ligated. The risk of embolisation with initial arterial ligation is probably small as once ligated, the venous system rapidly collapses. It is more important to handle a very vascular encapsulated tumour carefully to reduce the risk of embolisation.*

**Local excision**

The surgical dissection plane is directly onto the tumour capsule and the mass is ‘shelled out’ from the surrounding tissue. This is the least invasive and easiest method, however as microscopic disease will remain within the tumour bed, local excision must be confined to being benign tumours with negligible risk of recurrence and is **contraindicated in all malignant and invasive benign tumours**. Tumours amenable to local excision include lipoma, histiocytoma and certain adenomas, for example perianal adenoma.

**Wide, local excision**

For benign tumours that do not have a distinct capsule, excision of the tumour together with a margin of tissue is indicated. Gross tumour should not be observed within the adenoma.

**Wide, local excision**

For benign tumours that do not have a distinct capsule, excision of the tumour together with a margin of tissue is indicated. Gross tumour should not be observed within the

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Adipose tissue is not considered a fascial plane.

For dermal tumours, the panniculus muscle provides an effective fascial plane in most instances; for subcutaneous tumours excision of aponeurosis, fascia or deeper muscle may be required.
dissection plane at any time. The margin of normal tissue required varies with the tumour type, grade and local invasiveness. A margin of 2 cm is often quoted, but a wider margin may be required with high grade malignancies to ensure the removal of all microscopic disease and similarly a smaller margin may be appropriate depending on the tumour location – individual assessment is required. The tissue margin must extend in three dimensions all around the mass. Often the deep margin is neglected. As tumours rarely cross fascial planes, the deep dissection can terminate one fascial plane beyond the tumour.

**Compartmental resection**

Tumours with aggressive invasion into local tissue or that have arisen from anatomical structures (such as muscle) may require resection of the complete anatomical structure. This requires careful preoperative planning with advanced imaging (CT or MRI) to determine the extent of the tumour and subsequent excision required as well as ensuring that reconstruction of the resulting deficit can be achieved.
Closure of a wound using a surgical technique is usually the quickest and often the most cost effective method in achieving resolution of an open wound for our patients. Reconstruction of large skin and deeper tissue deficits is obviously a key skill in surgical oncology. In these situations having a choice of a number of options of closure and utilising multiple techniques with confidence is essential in achieving successful results.

For all surgical techniques, but in particular in relation to closure of skin wounds, an appropriate surgical technique is essential. The basic principles of surgery were summed up by Halsted in the 19th century.

**Halsted’s Principles of Surgery**

- *Strict asepsis*
- *Gentle tissue handling*
- *Accurate hemostasis*
- *Maintenance of adequate blood supply*
- *Careful approximation of tissues*
- *Avoidance of tension in tissues*
- *Obliteration of dead space*

**Tissue handling and instrumentation:**

Avoid the use of large rat-toothed forceps as these can cause considerable trauma to wound edges, especially if repeatedly used for assessing wound approximation. I prefer use of either an Adson or Adson-Brown thumb forceps or a Debakey forceps. Better still, if repeated manipulation of a skin flap will be required use either a pointed reduction forceps or place stay sutures. Correct application of the scalpel blade in a perpendicular manner to the skin surface is important to avoid partial thickness ragged incisions which will promote more inflammation. Careful blunt dissection with a blunt tipped Metzenbaum scissors or Mosquito haemostats is used to undermine skin or dissect between fascial layers.
Other equipment required are a marker pen and ruler to measure margins. Intermittent lavage of large flaps or placing saline soaked sponges over them is necessary to prevent dessication. Copious lavage of the wound site prior to closure is also advised to remove any residual debris. Electrosurgical coagulation is very useful for larger procedures to speed up operating time and prevent haematoma formation. It is important to avoid excessive use especially in areas that may be under tension or with reduced vascularity as it will cause considerably more inflammation.

**Suture material**

As previously discussed the initial strength of a wound is due to the fibrin clot and therefore minimal. Until days 7-14 when collagen is deposited into the wound, the sutures must support the wound. Therefore correct suture selection and avoiding prolongation of the inflammatory phase so that wound healing occurs rapidly is critical. All suture materials act as a foreign body within the wound, which will therefore tend to slow wound healing. Therefore use of a suture material must be advantageous to the wound and exceed any deleterious side effects associated with it. There is now no place for the older natural suture materials such as catgut that elicit a strong inflammatory reaction within the wound. These suture materials breakdown due to this inflammatory reaction which makes them also unreliable within the wound. The modern absorbable synthetic suture materials are absorbable by hydrolysis and elicit a minimal inflammatory reaction within the wound. The degree of suture reaction elicited is proportional to the amount of suture within the wound. The amount of suture depends on the diameter of the suture and the suture pattern used with much more suture present for interrupted compared to continuous techniques.

Suture selection is generally based on surgeon preference and experience. However use of monofilament sutures is advisable for most wounds as there is less tissue drag (and therefore less trauma) and allow less bacterial adherence. This later point is especially important in contaminated wounds. I prefer not to use multifilament suture material for skin suturing as it generally elicits much more inflammation. For skin suturing I prefer to use either monofilament nylon or polypropylene, generally size 2 to 3 metric (3/0 – 2/0 USP). I use the larger size for only large/giant dogs.

For the subcutaneous tissues, sutures need to be absorbable and either monofilament or multifilament synthetic absorbable sutures can be used, although multifilament is
avoided with any contamination. My preference is for a monofilament in all cases and I generally use either polydioxanone (PDS, Ethilon) or glycomer 631 (Biosyn, Covidien), although if there will be minimal tension present and rapid healing anticipated then poligecaprone (Monocryl, Ethilon) or Caprosyn (Covidien) are alternatives. These can be especially useful in cats as they subjectively appear to cause less reaction. For most fascial planes my suture preference is for one of the longer acting absorbable monofilaments, such as polydioxanone (PDS, Ethilon) or polyglyconate (Maxon, Covidien). The size of suture depends on the tissue but is generally 2 metric (3/0 USP) for the subcutaneous tissue and size 2 to 3.5 metric (3/0 – 0 USP) for the fascia depending on the tension and size of animal.

Assessment and Planning
Surgical planning, whether for an open wound or for tumour removal, requires an accurate estimation of the tissue deficit that needs to be closed. Various options for closure of the wound are then assessed and ranked according to the likelihood of the most rapid closure and return to function for the patient. This is then balanced against surgeon experience, patient management and client acceptability. The closure options available will depend on the region where the wound is and the availability of local skin. It is very common to utilise a combination of techniques especially for large reconstructions. Therefore a thorough knowledge of the available closure options is essential.

The surrounding skin is manipulated to determine its local tension and availability (a process that my colleague Jonathan Bray terms 'scrunching!'). This allows assessment of whether the wound can be closed by mobilisation of the local skin or if more distant flaps will be required. This step is initially performed with the animal conscious and in various normal positions. When under anaesthesia I repeat this before the hair is clipped to assess the cosmetic effect. I then repeat it after the clip to ensure that sufficient hair has been clipped. After position in surgery I repeat the ‘scrunch’ to ensure the area is sufficiently draped and that the patient position is ideal. I scrunch again after I have drawn the required margin around the tumour to ensure that with this margin closure can be achieved. After tumour removal the wound edges will retract and the defect will look considerably bigger. Scrunching now may be more difficult but should be possible
(manipulate the skin with stay sutures attached to the edges). If I have been satisfied up to now I can be reasonably confident that local closure will be possible. The same process is undertaken if skin is to be taken from another site (as with transposition flaps and axial pattern flaps) to assess the ability to close this donor site can be made.

When preparing the site I will generally clip wide enough so that I have at least two options for closure possible, especially with more challenging reconstructions. As a default I will always clip and prepare more skin than obviously necessary. Obviously owners need to be warned of this prior to surgery.

Surgical Drains
Obliteration of dead space is one of the key principles of successful surgery. Dead space will inevitably fill with exudates from the wound and if this continues to collect can lead to a separation of fascial planes. Apposition of the tissue layers is prevented and this will at least delay healing but can lead to wound dehiscence. In the presence of bacterial contamination, infection of the dead space will lead to abscessation.

Most open wounds will be able to drain through the wound by gravity, although if there is a ventral pocket additional drainage may be required. For closed wounds, drains are needed to control the dead space by removing any exudates that collect in the area. Dead space can be controlled by careful layered closure of deeper wounds with interrupted sutures or continuous suture lines. However to remove the exudate that will collect in the remaining dead space, wound drainage is required. If closure of dead space is not possible due to important local structures drainage will definitely be closed.

Use of pressure bandages can also be used to close dead space/restrict movement. Wound drains are classified as either passive, active or sump.

**Passive:** Passive drainage is performed using radioopaque latex Penrose drains. These are available in different widths but the basic principle is that there will be gravity dependent flow of fluid over the surface of the drain. Therefore it is obvious that Penrose drains must exit at a site ventral to the area to be drained. The drain is usually anchored in a dorsal position with a single skin suture that goes through the skin, tacks the drain and exits out through the skin. There is no advantage to having a separate dorsal hole through which the drain enters. It is best not to place the drain directly below the closed wound incision. It is also very important not to exit drain through the closed wound.
incision as this will delay healing, but to exit it through a separate ventral exit site. At this position the drain is anchored to the skin with a single suture.

The disadvantage of Penrose drains is that they are often unable to adequately drain large areas, however in this case multiple drains may be placed with a layered closure. Passive drains are also messy and the exit site must be covered to collect the exudates and to prevent introduction of bacteria. This bandage will need to be changed regularly to assess the level and type of fluid production.

The resolution of dead space can be slow with Penrose drains and it can be difficult to decide when to remove them, as assessment of the rate of fluid production is tricky. Penrose drains are usually maintained for 3-5 days or when the production is minimal. Drains will elicit some fluid production themselves, therefore once fluid production appears to tail off and stabilise, removal should be appropriate.

**Active:** Active or closed suction drains have **considerable advantage** over passive drains. They rapidly eliminate dead space, leading to a good approximation of underlying tissues and thereby a quicker cessation of drainage. They are less messy as the fluid is collected in the vacuum container, which also allows calculation of fluid production. This is very useful in determining the progression of the dead space obliteration. They do not require bulky bandaging over the wound site but instead can be secured with stockinette or ties. These drains are placed into the dead space and are then exited (usually with a swaged-on needle with commercial drains) at a site distant from the wound. They do not rely on gravity. Active suction drains are dependent on creating a vacuum within the dead space, therefore it is essential that the primary wound has been completely closed. Obviously they cannot be used in combination with passive drains and if primary wound dehiscence does occur then the drain will become ineffective. The disadvantage is that they are more expensive, although the reduced bandaging and hospitalisation required will usually offset this. Drains are produced by many companies, with my preference for the less bulky vacuum containers that can be easily removed, emptied and replaced. Homemade drains can also be made using butterfly catheters and vacutainers.
Managing Skin Tension

There are many strategies to manage skin tension that can be utilised during surgery. However the key to consistent successful management is the anticipation of tension during the initial surgical planning stages (see scrunching earlier). Anticipated tension can then be managed using a combination of techniques before, during and after surgery.

Preoperative techniques

Assessment of tension lines: tension lines have been mapped in the dog and cat and can be useful when planning excisions and closures. In general the length of the incision is made parallel to these lines, otherwise there is a greater tendency for the wound to widen. However there can be considerable variability between breeds and the maps are somewhat inaccurate, particularly on the limbs. This can confuse planning and closure. An easy way to assess the direction of the tension lines following a tumour excision is to examine the shape a circular wound assumes. An initial circular wound will be stretched into an elliptical shape, whose long axis is parallel to the tension lines. This ellipse can then be lengthened (to prevent dog ears) and closed.

Always start with a CIRCULAR incision when excising skin masses (which are mostly circular) rather than an elliptical incision. Tension lines mean that most circular defects change into an elliptical shape. This means that only enough skin as necessary is removed

Presurgical skin-stretching: skin is a viscoelastic tissue and the application of a stretching force over time allows the skin to extend beyond its inherent elasticity. The most commonly used technique is pre-suturing of skin, a technique used exclusively in the distal limbs for smaller skin deficits. Tension vertical mattress sutures are placed across the elective surgical site to stretch the skin on opposite sides. Sutures are placed under local anaesthesia, sedation or short GA 24 hours prior to intended surgery. The bites are placed about 3-5cm from the edges of the intended excision margins. A number of sutures are placed along the length of the wound and the sutures when tied place the surrounding skin under tension. For large defects, in particular on the trunk,
skin stretchers (as described by Dr. Pavletic) can be utilised. These are made of adhesive Velcro® pads that are glued (with tissue glue) to the surrounding skin. Velcro tape is then attached and stretched between the pads across the elective surgical site. These can be adjusted 3-4 times a day to keep the skin under continuous tension to increase recruitment of local skin. These are kept in place for 1-4 days (with the greatest gains at 3-4 days) and may also be used postoperatively to reduce incisional tension. The disadvantage is that they may be difficult to maintain in position, especially in the boisterous animal.

**Patient position:** correct patient positioning is essential when planning surgery. Releasing skin that is trapped under the recumbent animal may mobilise more skin and should be routinely performed prior to the final prep and draping. Placing pads under the animal may help to mobilise skin, for example pads under the dependent scapula and pelvis for large lateral flank wounds. Positioning the limbs in normal anatomical positions is particularly important when working in the inguinal or ventral pelvic positions to aid wound closure (for example bilateral caudal mastectomies).

**Operative techniques**

*Undermining skin:* correctly undermining skin is a crucial surgeon skill in releasing tension and mobilising skin. Knowledge of the vascular anatomy of the skin is essential. If present, the panniculus muscle must be preserved when undermining skin. This is because the major blood supply to the overlying skin (the deep subdermal plexus) is intimately associated with it. Where there is no panniculus muscle (middle and distal limbs), 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. Knowledge of the position of the direct cutaneous vessels should avoid damage to them when dissecting. Use careful blunt dissection with a blunt tipped Metzenbaum scissors or Mosquito haemostats (preferable near vascular pedicles to avoid disastrous consequences) to undermine skin or dissect between fascial layers. For skin that is firmly adhered to an underlying granulation tissue
bed when closing open wounds, use of a scalpel blade is best to release the edges (for the first 1-2cm). Wherever possible, preserve small feeder vessels encountered during dissection. 

The risks in undermining are vascular compromise and creating excessive dead space.

**Geometric patterns for closure**: particular geometric patterns can be utilised to close certain wounds shapes. These closure patterns can be useful in areas where there is limited local skin, however as they rely on the elasticity of local skin there can be considerable tension, particularly at points of intersection of multiple suture lines (with X and Y configurations). These are common points of wound dehiscence. It is generally preferable to close wounds in a linear or curvilinear fashion when possible. With circular and elliptical defects, sutures are placed to halve the defect to achieve good apposition along the length of the incision. Dog ears can occur at the incision ends of circular and elliptical defects, but careful suturing or excision of small amounts of skin will achieve a cosmetic closure. A length to width ratio of 4:1 avoids dog-ears at the ends of incisions, but I feel this usually leads to excessive skin excision especially for excision of skin tumours and is rarely necessary.

See the following diagrams for examples.
**Releasing incisions:**

**Single** – by making an incision parallel to the wound on one side, the intervening skin can be undermined and slid across to close the primary incision. This technique is useful in areas where the original wound is over key structures such as tendons, nerves, vessels or bone (especially used following plating of the distal limb), whereas the releasing incision is in a less critical position. A single releasing incision is made approximately 3 to 10cm from the wound depending on the size of the wound, intended position of the releasing incision and the regional skin laxity. Blood supply to the intervening skin is from either end (this is also called a bipedicle flap). The releasing incision is left to heal by second intention (this will probably take 4-6 weeks) or can be closed primarily if there is sufficient adjacent skin.

**Multiple** – rows of multiple incisions can be made on either side of a wound (in particular when reconstructing defects on the distal limb) to aid closure. The incisions are at least 1cm from the wounds, are approximately 1cm long and at least 1cm apart. A further row of incisions can be made 1-2 cm from the initial row. Only enough incisions are made to release the tension on wound, which is usually held near to apposition when making the incisions. If this technique is used for defects of 25% of the circumference of the limb then, the cosmetic appearance is good whereas if the defect is 33% then cosmesis is poor. The main concern with this technique is that there can be some compromise to the vascularity of the skin, especially if this is an area under tension. A long single releasing incision provides maximum tension relief compared to multiple rows of small incisions.
**Walking sutures**: these are used to move skin across a defect, to obliterate dead space and to distribute tension across a wound. The sutures are placed by taking a bite of the undermined skin followed by a bite of the underlying fascia or connective tissue but at a point 2-3 cm closer to the middle of the wound. By staggering rows of these sutures on either side of the wound, the skin is advanced towards its centre, as the sutures are tied. This technique can be used to a stage where the wound edges are near to apposition and can be closed. Absorbable sutures of 2 metric (3/0 USP) are used for these sutures and they are spaced at least 2-3 cm apart. The skin overlying these sutures is usually dimpled but this will resolve as the suture is absorbed. Placement of these sutures is commenced at the deepest portions, and it is useful to preplace all the sutures in a row before tying. Care is needed to avoid direct cutaneous vessels. Remaining dead space will still need to be controlled using drains or bandages. A possible complication is the formation of multiple seromas that do not communicate.

Walking sutures are very useful in distributing tension across a wound surface to reduce tension on the primary suture line. They can also be used to close dead space but do not replace the provision of adequate drainage for most cases.

**V-Y plasty**: this technique is simple to execute and can be used to relieve minor tension in certain areas such as the eyelids. Closing the distal portion of the V as the lY, pushes a small triangle of skin forward along the line of the Y.

**Use of skin suturing tension relieving patterns**: the ideal situation is that the skin edges are under a minimal amount of tension and that the skin sutures are only required to keep the skin edges in apposition, to allow rapid epithelialisation. Tension relieving skin suture patterns are not to be relied upon as a sole source of tension relief and for larger wounds this is a sure route to dehiscence. The skin edges are generally unable to withstand significant tension as this leads to vascular compromise and necrosis of the skin edges. However certain suture patterns can be useful in relieving minor tension or intermittent tension. Simple interrupted sutures are easy to place and commonly used but are more time consuming to place. My personal preference for nearly all wounds is interrupted cruciate
sutures using 3/0 swaged-on monofilament polypropylene or nylon (I use 2/0 for large dogs or on the thicker dorsal skin). Compared to simple interrupted they provide a stronger closure, resist tension, prevent eversion and are quicker to place. If small gaps are present or very accurate placement is required I will use occasional simple interrupted sutures. Skin staples can be very useful for rapid placement, but are only suitable if there is no tension and are placed in relatively thin skin. They can easily pull out or devitalize the skin edge if the vascularity of the skin is reduced or there is increased tension.

Vertical and horizontal mattress suture patterns are placed away from the wound edges. Stents of tubing or buttons can be used to prevent suture cut through or impairment of skin circulation. Close daily inspection for evidence of skin necrosis is necessary. The horizontal mattress suture is more likely to cause a zone of vascular compromise compared to the vertical mattress. Vertical mattress as well as far-near-near-far and far-far-near-near suture patterns are placed perpendicular to the wound and therefore cause less vascular compromise.

Intradermal suture patterns allow excellent apposition and cosmesis, but are not advisable if there is considerable tension as they will increase the vascular compromise at the skin edge.

**Local flaps (sub-dermal plexus flaps)**

Pedicle grafts are partially detached segments of skin and subcutaneous tissue that receives its vascular supply from the pedicle (base) of the flap. If this type of flap is elevated adjacent to the wound then it is termed a local flap. These are also termed deep subdermal plexus flaps as they depend on an intact deep subdermal plexus entering the flap for survival. These flaps can be developed if a wound is located adjacent to an area of loose elastic skin that can be mobilised. It is important to remember that this may lead to a deficit at the donor site that needs to be closed. As these flaps are dependent on the subdermal plexus, they are generally not applicable to very large deficits. With all these flaps great care is needed in handling to minimise damage to the vascular supply. If the flap is adjacent to direct cutaneous vessels, they can be include in the base of the flap or alternatively an axial pattern flap can be utilised.
Advancement flaps

- These are local flaps that are elevated and advanced forwards over the defect.
- They are developed parallel to lines of least resistance – assessment and scrunching around the circumference of the wound identifies the best orientation of the flap.
- The flap width is determined by the width of the defect. The flap is developed using two diverging incisions.
- The flap is undermined and advanced into the defect.
- There are no rules regarding appropriate width:length ratios as regional vascularity varies. However it is advisable to have a flap with a base slightly wider than its body.

Rotation flaps

- This is a semicircular flap that rotates into the adjacent wound. Again this flap relies on stretching of the undermined skin but in a semicircular manner.
- Traditionally this flap has been described with an arc of rotation four times the length required to rotate the flap into the defect. This however is usually unnecessary in dogs and cats and the flap is developed in a stepwise manner until it can close the wound.
- In my experience these flaps are infrequently indicated.
Transposition flaps

- These are very useful local flaps as they supply additional new loose skin into the wound. They do require more detailed planning and assessment prior to use and a donor wound is created that needs to be closed.
- These flaps are developed from loose skin that is within 45 to 90 degrees of the wound deficit. The long axis of the flap is developed parallel to tension lines, as this makes closure of the donor wound more straightforward.
- The width of the flap corresponds to the width of the defect adjacent to the proposed flap. The pivot point of the flap is identified and a measurement is made from this point to the farthest position of the defect. This distance will be equal to the distance from the pivot point to the farthest point of the flap. Once elevated the flap will be rotated through an arc into the defect.
- As the arc of rotation of the flap increases the length of the transposition flap decreases and a dog ear can develop at the base.
- This is a very versatile flap that can be used in numerous locations on the body. On the distal limb the flap is created parallel to the long axis of the limb.

Axial pattern flaps

Axial pattern flaps are pedicle grafts that contain a direct cutaneous artery and vein. The regions of skin that are supplied by most of the main direct cutaneous vessels have been mapped in dogs and cats. This allows consistent identification and mobilisation of large skin flaps in one stage with confidence that there is a reliable vascular supply. These can then be used for the closure of many large adjacent defects.

Axial pattern flaps are generally rectangular in shape; although they can be modified with a right angle extension (this area of the flap is dependent on the deep subdermal plexus). The planning and execution of an axial pattern flap must be meticulous, as if there is failure of the flap, the results can be catastrophic. Flap failure is generally due to technical error (failure to identify perimeters correctly, failure to preserve the vascular pedicle, failure to manage dead space etc.). There will also be a significant donor site to be closed. Axial pattern flap surgery is time-consuming with consequent lengthy anaesthesia.
The elevated flap can be rotated into position with a base of skin still intact or this base can be incised to create an ‘island’ flap. This reduces the wastage that results in with rotation when the base is intact (when a large dog ear can develop). However the island flap is now completely dependent on its vascular pedicle for its blood supply and as there is no skin attachment there is a risk of kinking the pedicle with resultant vascular compromise. All the principles of surgical wound closure must be adhered to especially dead space management.
In the postoperative period the flap margins should always appear pink and viable. Cyanosis or excess swelling are indicators of vascular compromise and potential impending necrosis.

Axial pattern flaps provide the ability to resect large tumours and close large defects with vascularised skin. However flap failure is a castastrophic disaster so surgery should be not undertaken lightly!

These flaps have also been used for microvascular transfer techniques where the cutaneous vessels are identified; the flap is elevated and then transferred to a distant site where the vessels can be anastomosed to large local vessels. This procedure requires considerable experience and expertise and are very rarely indicated.

**Free Skin Grafts**

Free skin grafts are a versatile and accessible method of closing small to large sized wounds, usually following a period of open wound healing. In difficult areas such as the distal limbs, free skin grafts can be utilised to achieve durable epithelial cover. Full thickness grafts have the advantage of including the adnexal structures which improves cosmesis and are by far the most commonly used graft in dogs and cats.
Free skin grafts lack a vascular attachment on transfer to the wound and must depend on imbibition of wound fluid from the recipient bed for the first 48 hours. It follows therefore that having a healthy vascular bed plays a key role in the initial preparation for a free skin graft. The most common recipient bed is clean healthy granulation tissue, but healthy muscle and periosteum can also support a graft. Chronic granulation tissue (pale, poorly vascularised) is unsuitable but can be coverted back to good tissue by serial debridement and bandaging for a few days prior to grafting.
The graft is harvested from an area where there is plenty of free skin. This is then prepared by removing all subcutaneous fat or muscle. The graft is then meshed by placing small incisions at staggered intervals. This is to allow effective drainage of fluid that may collect beneath the graft. The graft is orientated in the correct direction of hair growth, secured to the recipient site with sutures, overlapping the edges by 2-5 mm.

Any accumulation of debris, blood, purulent material or foreign material between the graft and the recipient site will impair plasmatic imbibition (absorption of recipient site wound fluid) and will lead to ischaemic necrosis of the graft. Therefore the recipient bed should be smooth, clean, free of infection and have all haemorrhage controlled. For the first 48-72 hours the graft will appear swollen and slightly cyanotic. All subcutaneous fat must be removed to allow imbibition to occur. Vascularisation of the graft occurs via entry of capillaries of old vascular channels (inosculation) or creation of new vessels (revascularisation). These vessels are fragile and any movement of the graft will prevent a successful ‘take’ – therefore careful immobilisation of the graft to the recipient bed by carefully suturing in position and subsequent bandaging to immobilise the area is very important. The initial bandage (an absorbent foam, silicone dressing with absorptive secondary layer, or possibly vacuum-assisted closure) to maintain moist wound conditions is recommended) is usually left in place for at least 72 hours (I usually wait 3-5 days unless concerned). Sedation is essential for the first bandage change to prevent excessive movement. Extreme care is needed when lifting off the bandage material in case there is some adherence to the graft. The bandage is then changed every 2-3 days for about 10-14 days. A light dressing is then placed for a further 2 weeks to protect the initially delicate epithelium.

Should the graft appear to undergo necrosis, all may not be lost as the deeper dermal and adnexal layers may survive and epithelialisation can occur from these areas. Therefore avoid debridement of the graft even for at least 5-6 days even if it looks as if full necrosis has occurred.

An alternative to full thickness meshed grafts is the use of punch grafts. These are harvested with a biopsy punch and placed in holes created in the granulation tissue bed. This is a very useful and fast technique for closure of small wounds, especially if more movement is anticipated.
Complications of wound closure

Seroma/haematoma
Fluid or blood that collects between tissue layers will significantly delay healing. Dead space management is a key element of surgical wound closure (see earlier section on drains). However if a seroma develops due to poor drain selection, failure to close dead space, premature drain removal, a high motion area (the cervical region, shoulder and inguinal region are common sites for development), then management is required as if further fluid collects in the dead space then enlargement of the area can lead to further disruption or enlargement of the wound. This can place pressure on the wound, leakage of fluid from the sutured incision and dehiscence. Should bacteria gain access to the area, then the fluid can be an ideal medium for infection to develop.

Management depends on the extent of the seroma. Monitoring of small accumulations is appropriate, with needle drainage if necessary. These will often resolve without treatment. Larger or rapidly developing accumulations can be needle drained (with strict asepsis) and then bandaged to control dead space or a new drain (active or penrose) may need to be placed. Placement of active drains can be achieved in a closed manner - the swaged-on needle drain can be placed through the skin, placed through the seroma and then manipulated to exit at a distant site. The drain can then be pulled through into the seroma cavity. The drain is secured at the distant exit site. This technique is considerably easier then having to open the wound again and place a penrose drain. With active drainage the seroma cavity (by now usually lined with granulation tissue) will be sucked into apposition and usually will rapidly close.

Wound dehiscence
Pavletic has identified 12 potential causes of dehiscence – knowledge of these before embarking on surgery helps the anticipation and avoidance of this major complication.

Nearly all of these causes are technical surgeon errors!

• Excessive tension leading to ischaemic necrosis of wound edges and suture pullout
• Inappropriate suture placement too close to skin edge (within 5mm there is a zone of increased collagenase activity which increases the risk of suture pullout)
• Suture placement in scar tissue which has poor suture-holding capacity
• Inappropriate suture material – size, type (especially avoid multifilament for skin), pattern, placement etc. for skin type
• Inappropriate suture pattern leading to vascular compromise of skin edge and subsequent necrosis
• Premature removal of sutures
• Premature closure of inflamed skin leading to skin necrosis
• Exudative wound leading to maceration of skin edges
• Underrun skin edges with major dead space or underlying infection, foreign bodies, necrosis, neoplasia
• Poor postoperative management with patient self-trauma of wound or lack of immobilisation, poor bandage technique, iatrogenic bandage injury
• Delayed healing due to corticosteroids (usually with long-term treatment) or other agents
• If all the above are excluded – suspect an underlying healing disorder

Although any wound dehiscence is disappointing and frustrating, always use it as an opportunity to identify the cause and then try to avoid repeating the same mistake on this or the next wound!

Further reading


Small Animal Surgery, 3rd Edn., Fossum T.W., Mosby

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