Reconstruction with local subdermal plexus flaps

1. Introduction

Skin flaps are a simple, quick and relatively simple surgical technique which may be used to close cutaneous defects which are too large to be closed by simple apposition of the wound edges, or application of simpler techniques to manage regional wound tension.

A number of different flap types are available for use, depending on the size and location of the defect. In order to use local subdermal plexus flaps correctly, the surgeon needs to have a good knowledge of the following topics:

- Cutaneous physiology and blood supply
- Factors affecting wound healing
- Skin elasticity, mobility and skin tension lines

The surgeon should remember that these factors will vary between wounds and between patients and therefore any plan for wound closure should be tailored to the individual patient, with a consideration of the following:

- Shape and location of the wound
- Proximity of other vital structures or natural body orifices (e.g. mouth, eyelids, anus)
- Conformation of the patient and the amount of loose skin
- Static tension within the skin (skin tension lines)
- Dynamic tension within the skin (due to movement of a limb, head or neck)

2. Definition

A skin flap is a partially detached segment of skin & subcutaneous tissue, formed by incising the skin on three out of four quadrants of attachment, which is then stretched or rotated into position to close a nearby skin defect. The attached pedicle provides blood supply to the flap via the subdermal plexus, while vascular attachments are established with the wound bed. The vascular pedicle may be left attached (local or subdermal plexus flaps) or detached (distant flaps).

3. Indications & use

Local flaps are indicated if there is enough loose skin close to the wound defect, but regional attachment prevent it moving. This technique therefore transfers tension at the original wound edges to the edges of the relocated skin of the flap.
Wound healing after use of a skin flap may be more reliable than primary closure as:

- The flap is not affected by the local disease
- The flap has not had previous surgical interference
- The flap has a normal blood supply

**Advantages** of skin flaps compared to free skin grafts:

- The surgical technique is simple and economical
- The technique is applicable to most surgical sites, except large flaps of the distal limbs
- Skin flaps have predictable and good survival
- Skin flaps may be used to cover ischaemic wound beds
- Primary closure of the donor site is usually possible
- The cosmetic appearance is good, since full-thickness skin with a similar appearance to the recipient site is used

**Indications** for skin flaps

- Poorly vascularised wounds
- Areas which are difficult to immobilise
- Skin defects overlying defects in body cavities
- Wounds where padding and skin durability are required

Local skin flaps may be used in 2 main ways:

- Subject to pre-operative decisions, e.g. the planned use to reconstruct a defect following tumour excision
- Subject to intra-operative decisions, e.g. use of flaps to manage tension during wound closure

### 4. Classification

Skin flaps may be classified according to:

- Blood supply
- Tissue composition
- Location in relation to the recipient bed
- Direction of transfer
- Creation of a secondary defect
- Time interval between flap creation and use

#### 4.1. Classification of skin flaps by blood supply

Skin flaps may be classified as to whether they contain a direct cutaneous artery (DCA):

- Subdermal plexus flaps do not contain a DCA, and are known as random-pattern flaps
- Axial pattern flaps contain a DCA
To augment the blood supply to a random-pattern subdermal plexus flap, the base should be orientated so that it is near the regional direct cutaneous artery to increase perfusion pressure to the flap.

4.2. Classification by tissue composition

Simple skin flaps may consist only of skin, whereas compound flaps contain other tissues, such as muscle, fat, bone and cartilage.

Compound flaps include:
- Myocutaneous flaps: elevation of the skin & muscle as a unit, e.g. latissimus dorsi
- Musculocutaneous flaps: elevation of a muscle and the overlying skin, e.g. gracilis
- Labial advancement flaps: skin, muscle and mucosa are all elevated together as a unit

4.3. Classification by location of the flap in relation to the recipient bed

Skin flaps may be described as:
- Local flaps
- Distant flaps

4.3.1. Local flaps

Local flaps may be further classified according to whether they share a common border with the wound. Local flaps are elevated adjacent to the wound to be closed, and usually share a common border with the wound. Closure using local flaps is one of the simplest and most useful techniques if simple undermining and suturing is not sufficient. As a modification, interpolation flaps are created close to the wound to be closed, but the flap does not share a common border with the wound bed. This requires either a bridging incision between the donor and recipient sites, or formation of the redundant portion of the flap into a tube.

4.3.2. Distant flaps

Distant flaps are elevated from skin located at some distance from the wound to be closed. These distant flaps may either be transferred to the defect directly (distant direct flap) or indirectly (distant indirect flap).

4.4. Classification by direction of transfer

Skin flaps may also be classified according to the direction of mobilisation of the skin:
- Advancement flaps travel in a forward direction towards the wound
- Rotation flaps travel in an arc about a pivot point, e.g. rotating and transposition flaps

4.5. Classification by method of provision of skin

Skin flaps may be classified according to how they make additional skin available for closure. No technique can increase the total amount of skin on the body, and so there is always some cost to mobilising the skin. However, these techniques use a combination of the inherent elasticity of skin
and the regional variation of skin tension to allow skin to be mobilised and may, in many cases, allow the donor site to be closed.

- Advancement flaps provide additional skin by stretching the skin of the flap
- Transposition flaps provide additional skin by physically moving a segment of skin
- Rotating flaps provide additional skin by a combination of the above techniques

4.6. Classification according to secondary defect

Skin flaps may be classified according to whether a secondary defect is created:

- Advancement flaps and rotating flaps do not create a secondary defect
- Transposition flaps create a secondary defect

4.7. Classification according to interval between flap creation and use

Skin flaps may be divided according to whether there is a delay between elevating the flap and its application to the wound. Most flaps are elevated and used immediately. Delayed flaps are elevated and then sutured to the donor site. These flaps are then elevated in the future and then applied to the recipient wound. Distant indirect flaps are a form of delayed flap.

5. Principles of skin flap use

5.1. Steps to be taken in planning a flap

- Evaluate the shape and size of the wound to be closed
- Consider all possible flap designs and configurations
- Assess local skin tension and pliability – manually lift and push the skin

5.2. Influence of the shape and size of the primary wound

Although most wounds, either accidental or elective, are not neat geometric shapes, a consideration of the general shape of a wound will help to determine the most appropriate flap. Irregularly-shaped wounds may be trimmed to a simpler geometric shape to facilitate closure. This selection of closure based on shape may be modified by regional considerations such as localised areas of increased or reduced skin laxity and presence of other local structures, e.g. natural body orifices.

- Triangular wounds are usually closed with single or paired rotation flaps
- Square or rectangular defects are usually closed with single pedicle advancement flaps
- Square defects may be closed with paired, opposed rotation flaps
- Elliptical wounds may be closed with bipedicle advancement flaps
5.3. Flap design & blood supply

5.3.1. Theory of cutaneous circulation in skin flaps
Contrary to the widely held belief, increasing the width of the skin flap does not necessarily increase the total surviving length of the flap. Flaps created under similar conditions of blood supply may survive to the same length regardless of the flap width. Increasing length of the flap increases the likelihood of necrosis of the tip of the flap irrespective of the width of the base. In addition, the cutaneous circulation differs regionally and it is not possible to give a set length:width ratio. The blood supply to subdermal plexus flaps arborizes in a random fashion and a flap with a narrow pedicle could still support a relatively wide flap. The blood supply to the head and neck is generally greater than at other anatomic locations, which allows the creation of relatively long flaps (particularly advancement flaps) which would not be possible in other locations.

5.3.2. Practical tips
- Increasing the width of the base of the flap increases the chance that the flap base will contain a direct cutaneous artery
- Orienting the flap with its base in the direction of a direct cutaneous artery will improve its blood supply
- Procedures which limit the base of the pedicle, e.g. back-cutting, should be avoided
- Flaps with a base slightly wider than the width of the body of the flap avoids inadvertent narrowing of the pedicle
- The shortest flap which achieves the intended function should be used
- Two smaller flaps may be preferable to one larger flap
- The microcirculation in the flap is preserved by careful atraumatic technique and avoidance of tension

5.4. The ideal donor site
The ideal donor site for skin flap has:
- Abundant supply of mobile skin
- A location away from sites of tension or motion
- A base directed towards the regional direct cutaneous artery

An abundance of mobile skin allows a flap of sufficient size to be elevated and allows primary closure of any associated secondary defect. Use of a flap away from sites of motion reduces the incidence of dehiscence. Closure of wounds to provide protection for exposed vital structures may allow an exception to these rules. For instance, the use of a bipedicle advancement flap to close a wound over the point of the elbow results in an open wound on the lateral or medial aspect of the joint which is less subject to dynamic tension during movement of the joint and is left to heal by second intention. As indicated above, if the base of the flap is directed towards the regional direct cutaneous artery, the perfusion pressure within the subdermal plexus is likely to be greater and the likelihood of survival will be higher.
5.5. The ideal recipient site

The recipient bed should be free of necrotic tissue, foreign material and infection. A fresh granulation tissue bed is ideal. Chronic granulation tissue should be excised and the skin defect managed as an open wound to re-establish a fresh granulation tissue bed. In contrast to free skin grafts, local skin flaps can survive on avascular recipient beds, since their vascular supply is guaranteed through the pedicle. However, distant flaps require that adequate circulation is established via the recipient bed since the pedicle will eventually be divided.

5.6. The delay phenomenon

5.6.1. Principle

Skin flaps which are raised in two or more stages before transfer are more likely to survive than skin flaps transferred immediately after elevation. This is the delay phenomenon and occurs because the vascularity of the flap is improved and can offset the negative effects on circulation caused by manipulation of the flap, such as torsion and tension. The advantages of this flap is the improved survival of the flap and the potential to provide skin coverage for avascular wounds. The disadvantages of this technique are the need for more than one surgical procedure and the necessity for prolonged open wound management of the recipient site. The more routine use of axial pattern flaps and myocutaneous flaps has reduced the need for this technique. However, understanding the mechanisms behind this phenomenon may help to guide appropriate therapy for the failing flap with poor circulation. A number of mechanisms may account for this phenomenon, and these include both functional and anatomic alterations in the blood supply to the flap.

The underlying functional change is sustained vasodilation within the flap. This may be caused by:

- Denervation (reduced sympathetic supply)
- Ischaemia
- Release of neurohumoral mediators
- Opening of “choke” anastomoses between adjacent vascular territories (angiosomes)

The underlying anatomic change is an alteration in the capacity for blood flow to the flap. This may be caused by:

- Increased vessel diameter
- Increased vessel number
- Parallel orientation of vessels

The optimal time between flap creation and division of the pedicles varies according to species, with 2-3 weeks being appropriate for the dog.

5.6.2. Use

Delayed flaps are not commonly used in veterinary medicine. However, the distant indirect flap is a form of delayed flap, where a tubed flap is raised with 2 pedicles, one at each end. After an
appropriate delay, one pedicle is divided and transposed and moved. After another delay, the other pedicle may be divided and moved.

5.7. Principles of surgical technique

5.7.1. Preserve viability
- Atraumatic preparation & handling (stay sutures, skin hooks)
- Keep flap moist & cool with saline-soaked swabs

5.7.2. Ensure adequate blood supply
- Preserve any direct cutaneous arteries
- Handle flap gently
- Avoid excessively long flaps
- Avoid unnecessary narrowing of pedicle

5.7.3. Avoid tension
- Assess the tension and mobility of the regional skin & orient the flap appropriately
- Place rather than stretch into position
- Use walking sutures to distribute tension

5.7.4. Manage dead space
- Obliterate dead space with sutures and bandaging
- Drain dead space with active suction drains

5.7.5. Pre-operative planning
- Use template, e.g. swab or sterile paper from glove packet
- Vary the size until anatomically correct
- Draw flap on skin with pen

5.7.6. Intra-operative planning
- “Measure twice and cut once” to ensure the flap is the appropriate size
- For transposition flaps, develop the flap according to template
- For advancement flaps, and, to a degree, rotating flaps, continue elevating the flap until the flap may be used without tension

5.7.7. Relief of tension
If tension is present, which cannot be relieved by making a larger flap, then the following methods may be used:
- Make a relaxing incision in the skin adjacent to the flap (transposition flaps)
- Make a stab incision along the tension lines in the flap (rotation & transposition flaps)
- Make a back-cut in the base of the flap (rotation flap)
- Remove a triangle of skin (Burrow’s triangle) from the base of the flap (rotation flap)
The use of a relaxing incision in the adjacent skin avoids interference with the blood supply to the skin flap which is possible with the other techniques. With adequate undermining of the adjacent skin, it may be possible to close this secondary defect. The use of a Burrow’s triangle is not very effective in managing this local tension and making a back-cut in the base of the flap reduces the width of the pedicle, and these techniques are not recommended.

5.8 Post-operative care

Post-operative management of the patient and the skin flap comprises:

- Bandaging
- Drain management
- Analgesia
- Exercise restriction
- Daily examination of flap

5.9. Flap failure

Causes of flap failure:
The following factors may result in flap necrosis and failure:

- Avascularity
- Static tension on closure
- Dynamic tension on movement of the affected body part
- Underlying fluid accumulation, e.g. haematoma
- Infection
- Gravity effects

A poor blood supply is the most common cause of flap failure. As little as 10% of the normal blood supply may allow the flap to meet its nutritional requirements, although 90% of the blood supply is required for normal thermoregulation. Wound tension will retard wound healing and may cause separation of the wound edges. Tension, kinking and twisting of the flap will impair the cutaneous microcirculation. Fluid accumulation beneath the flap may interfere with the cutaneous microcirculation via a pressure effect and also interferes with the revascularisation of the flap from the wound bed. Infection of the flap is more likely in a wound with poor blood supply. Gravity is likely to have an effect in the blood flow in local blood vessels, although this does not seem to have a significant clinical effect. The survival of surgically created flaps with dependent and non-dependent bases seem to be similar. However, in traumatically created skin flaps, flaps with a dependent base have a lower area of survival.

Signs of flap devitalisation and failure

- Colour change: purple/blue
- Texture: dry, firm
- Temperature: cool/cold
5.10. Subjective assessment of flap circulation

A number of criteria are used in the assessment of the viability of the flap. However, all of these are subjective and may therefore be inaccurate. In addition, the appearance of the flap on a single examination represents just one moment in time and repeated assessments over time (e.g. twice daily) probably give a more accurate assessment.

The subjective criteria for flap viability are:

- Colour
- Texture
- Temperature
- Pain sensation
- Bleeding
- Blanching on pressure
- Hair growth

Colour change is an obvious change, but may be deceptive. Contused skin in traumatic flaps may survive if no further injury to the microcirculation occurs. Severe circulatory obstruction results in a relatively predictable series of colour changes from red to lavender to deep purple and finally to black. However, flaps with less serious vessel compromise may adopt a red or lavender hue, but then recover viability and a normal colour. In addition, darkly pigmented skin may not show any detectable colour change initially and the first sign of failure may be fissuring between the viable and non-viable parts of the flap. Flaps with venous or lymphatic obstruction may become soft and swollen and then more turgid. Flaps with a failing blood supply may become firm, dry and inflexible. A subjective assessment of the surface temperature of the flap is a simple method for determination of flap viability. Gentle palpation with the back of the index finger and comparison with the adjacent, undisturbed skin is used. Loss of viability is associated with a reduced temperature. However, an accurate assessment is difficult without using instruments under controlled conditions, and repeated palpation of the area may increase the surface temperature.

A failing flap may be expected to lose cutaneous sensation. However, most flaps are partially denervated on elevation and a lack of pain sensation in an otherwise responsive animal is not an accurate reflection of flap survival. Bleeding of the skin margins is often used as an assessment of the viability of the skin following surgical creation of a flap or for the assessment of the viability of traumatised skin during debridement. Its use in the post-operative period is traumatic and not without risk of impairing the circulation even further. However, this method of assessment may yield misleading information:
• Bleeding from the cut edges may not indicate that the cutaneous microcirculation throughout the flap is sufficient
• Bleeding will give an assessment of arterial supply, but not venous return
• Temporary vasospasm may result in a lack of bleeding from the edges, but the blood supply may return after this temporary setback
• The apparent presence of a good blood supply does not guarantee that the vascular supply will not be subsequently interrupted by trauma, oedema or thrombosis

Blanching of the skin in response to digital pressure and return of the normal colour within 4 seconds is a simple subjective assessment for the assessment of flap viability in human surgery. However, the skin of cats and dogs does not readily blanch on pressure and this method has little practical application. The regrowth of hair of the expected density is associated with the return of a good vascular supply, whereas sparse hair growth is seen in flaps with poor circulation. However, the return of hair growth occurs over a few weeks and is of no use in the early post-operative period.

5.11. Objective assessment of flap circulation

A number of more objective methods of assessment have been developed in human medicine to allow assessment of viability, both in failing flaps and also for the assessment of the optimum time for division of a vascular pedicle after a delay procedure. Although many of these methods have been used experimentally, they have not found widespread clinical use in veterinary medicine.

Objective methods of flap viability include:
  • Fluorescein dye accumulation following IV injection
  • Blood samples from stab incisions in the flap for pH, haematocrit and blood gas analysis
  • Laser Doppler flow measurements
  • Infra-red thermography
  • Percutaneous tissue oxygen measurements
  • Radio-active isotope clearance studies

5.12. Salvage for the failing flap

5.12.1. Experimental studies

There are many studies examining the development of the microcirculation within the flap and methods to prevent necrosis once the circulation becomes deficient. Studies of the delay phenomenon have also contributed to this knowledge. However, there is no drug with a consistent clinical action and it is difficult to make recommendations for therapeutic intervention.

Attempts to improve the blood flow in a failing flap include:
  • Altering the rheological (flow) characteristics of the microcirculation
  • Haemodilution vasodilators, e.g. isoxuprine
  • Calcium channel blockers inducing vasodilation, e.g. nifebidrine, diltiazem
• Angiogenic growth factors & L-arginine
• Adrenergic agonists and antagonists, e.g. acepromazine

Attempts to improve the survival of the flap in the face of poor blood flow include:
• Hypothermia
• Hyperbaric oxygen
• Calcium-channel blockers, e.g. nifedipine, diltiazem, verapamil
• Corticosteroids
• Free-radical scavengers, e.g. desferoxamine, superoxide dismutase
• Adenosine triphosphate

5.12.2. Potential recommendations

1. Corticosteroids
Corticosteroids appear to have a beneficial effect in improving flap survival under experimental conditions. This is mediated by sustaining anoxic cells, vasodilation, reducing tissue oedema and stimulation of cell metabolism. Many of these effects are mediated by inhibition of the synthesis of prostaglandins. However, some of these arachidonic acid metabolites are beneficial, including prostaglandin E, which induces vasodilation and prostacyclin, which inhibits platelet aggregation. Coupled with the potential negative effects on wound healing, these agents are not recommended for routine use.

2. Alteration of the blood flow characteristics
Depletion of erythrocytes and plasma proteins may improve the flow characteristics of blood within the flap. However, this is not a simple procedure and may have adverse effects on wound healing.

3. Topical dressings
Topical antibiotic ointments may improve flap survival by prevention of desiccation of the deeper ischaemic portion of the flap until revascularisation can occur. This is a simple and practical technique.

4. Hypothermia
Hypothermia will prolong the survival of free flaps and permits recovery after longer periods of ischaemia.

5. Hyperbaric oxygen
The administration of oxygen at pressures greater than atmospheric has a proven effect on the survival of skin flaps in human medicine. However, this method is largely impractical for routine use in veterinary medicine.
6. Leeches
Leeches may be used to remove blood from the microcirculation in flaps which become engorged because of venous obstruction. However, venous obstruction in the absence of arterial compromise is uncommon.

5.13. Management of the necrotic flap
If necrosis of a large portion of the flap occurs, then excision of the necrotic part should be performed as soon as the division between the viable and non-viable parts becomes apparent. Small areas of full-thickness or partial-thickness necrosis may be left to heal by second intention, as long as no infection is apparent.

The advantages of leaving areas of questionable viability are that the decision to remove it may be delayed until it is certain the skin is non-viable, the skin may recover from the apparent loss of viability and normal healing is not interrupted. However, this must be balanced against the disadvantages of potentiation of wound infection, slowing of wound healing by mechanical interference with wound contraction and impairment of the formation of granulation tissue below the non-viable skin.

6. Local flaps

6.1. Types of local flaps
- Advancement flaps
- Rotating flaps
- Flank fold flaps

6.2. Advancement flaps

6.2.1. Types:
- Single pedicle  commonest flap
- Paired single pedicle  H-plasty
- Bipedicle  relaxing incision
- V-Y advancement  used primarily for tension relief

6.2.2. Use & principles
Their use is limited to areas where there is loose skin, e.g. the lateral flank, neck and portions of the head. Additional skin is made available for wound closure by making use of the inherent elasticity of the skin and no new skin is moved into the wound. These flaps are developed so that they advance perpendicular to the lines of skin tension. Unless the flap is created carefully, this skin tension may promote wound dehiscence or may distort the recipient wound, which is important if this wound is close to a natural orifice or other mucocutaneous junction, e.g. anus, eyelid. There is no secondary defect to close.
6.2.3. Single pedicle advancement flap

**Definition**
This is a rectangular flap whose tip shares a common border with the wound to be closed. It is usually a rectangular portion of skin advanced parallel to its long axis. However, short fat flaps may be used instead of these long thin flaps.

**Types**
- Single flap
- Paired flaps (H-plasty)

The use of 2 opposed smaller flaps (H-plasty) rather than one large flap may be more effective.

**Use & principles**
Advancement flaps are the simplest of the local flaps and are suited for the closure of square or rectangular defects.

**Design & technique**
The width of the flap is equal to the width of the defect to be closed. The flap length is determined by the length of the defect and the inherent elasticity of the skin. The flap is developed in a progressive manner until the wound can be closed without excessive tension. The parallel incisions may be made in a slightly diverging manner to prevent inadvertent narrowing of the base of the pedicle. With increasing flap length, there is a tendency for dog-ears to develop. Burrow's triangles may be used to prevent dog-ear formation, but these incisions have a minimal effect on promoting flap mobility.

6.2.4. Bipedicle advancement flap

**Definition**
This is a rectangular portion of skin, whose long axis is parallel to the long axis of the wound, and which is advanced perpendicularly to its long axis.

**Types**
The bipedicle advancement flap is a simple flap of a single type.

**Use & principles**
The use of 2 pedicles allows longer flaps to be created. Occasionally, necrosis may be noted at the junction of the vascular territories of the 2 pedicles. A relaxing incision is a bipedicle advancement flap by design.

**Design & technique**
The width of the flap should be the same or greater than the width of the defect to be closed. The length of the flap should equal the length of the defect, although the incision may be lengthened until the primary wound may be closed without tension, if primary closure is the goal. The orientation of the flap depends on the shape of the wound. Advancement of the flap is facilitated if the incision is curved with the concave aspect towards the defect. The secondary defect may be closed by
undermining and suturing, by the use of another local flap (this time harvesting skin from a region where there is more abundant loose skin) or may be left to heal by second intention.

6.3. Rotating flaps

6.3.1. Types of rotating flaps

- Transposition flaps
- Interpolation flaps
- Z-plasty transposition
- Rotating flaps

6.3.2. Use and principles

These flaps are the most versatile of the local flaps. “New” skin is moved into the wound for closure and tension is less of a problem in the closure of the primary wound. However, a secondary wound is created and tension may limit closure of this defect.

6.3.3. Transposition flaps

*Definition*

A transposition flap is a rectangular flap created within 90° of the long axis of a defect. One long edge of the flap is shared by the defect to be closed.

*Types*

- 45° transposition flap: useful for triangular defects
- 90° transposition flap: most useful flap

*Use & principles*

Transposition flaps are the most versatile of the local flaps and additional skin is moved into the wound. There is a loss of length of the flap and an increased likelihood of dog-ear development with an increasing arc of rotation. A 90° transposition is the most useful and 180° transposition is the maximum possible. Measurements are critical if both sites are to be closed. The 90° transposition flap is elevated parallel to the lines of greatest tension (and therefore placed in the donor site perpendicular to the lines of tension), which aids both the development of a larger flap and transverse closure of the donor site.

*Design & technique*

The width of the flap is equal to the width of the defect. The length of the flap is equal to the length of the most distant aspect of the wound edge from the pivot point.

The local skin tension & mobility is assessed and the width and length of the flap are marked. Incisions are made in the skin to outline the flap, with curved rather than angular edges. The flap is elevated and placed into the recipient site and the defect closed, followed by closure if the donor site if this was the goal.
6.3.4. Interpolation flaps

**Definition**
The interpolation flap is a modification of the transposition flap which is developed from skin which does not share a common border with the wound. As a result the flap must cross intact skin between the donor and recipient beds.

**Types**
The flap may be subject to a variable arc of rotation, as for the transposition flap.

**Use & principles**
The principles are similar to the transposition flap, but they are not commonly used in veterinary medicine.

**Design & technique**
The designs and technique are similar to the transposition flap. The exposed underneath surface of the interpolation flap may be managed by:
- Healing by second intention
- Covering it with a skin graft
- Closing it as a tube
- Incorporating it into the skin between the donor and recipient sites with a bridging incision

For the first three options, once the recipient site has healed, the redundant skin may be left as a tube, excised or incorporated into the skin adjacent to the wound. Excision is the logical option, but the skin may be retained if it is anticipated that further regional reconstruction will be required. Practically, a bridging incision is usually used, and no further management is needed once the wound has healed.

6.3.5. Z-plasty transposition flap

**Definition**
This technique involves the transposition of 2 interdigitating equilateral triangular flaps of skin adjacent to the wound.

**Types**
The Z-plasty may be performed singly or as multiple interconnected Z-plasties. The length of the limbs and the angles between them may be varied.

**Use & principles**
Shortening of the effective length of a segment of skin in one direction is accompanied by an effective gain in length in the perpendicular direction. The local skin must be loose and elastic to allow the transposition of the skin flaps, and this technique may not be applicable in areas with extensive scarring and fibrosis.

This technique may be used:
• To provide a minor change in local wound tension, e.g. close to a bodily orifice, such as eyelids
• To lengthen restrictive scars
• To change the direction of a scar into a less obvious pattern

The third application usually requires the use of multiple adjacent Z-plasties in a zig-zag fashion, and is chiefly a cosmetic technique and therefore not likely to be applicable in our patients.

**Design & technique**

The central limb of the Z is oriented in the direction of the desired gain in length. The two triangles are undermined, transposed and then sutured in their new position.

The net gain depends on the angle of the other incisions to the central limb:

<table>
<thead>
<tr>
<th>Angle of Z-triangles</th>
<th>Net gain in length</th>
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<tbody>
<tr>
<td>$60^\circ$</td>
<td>75%</td>
</tr>
<tr>
<td>$70^\circ$</td>
<td>100%</td>
</tr>
<tr>
<td>$90^\circ$</td>
<td>120%</td>
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The net gain in length also depends on the length of the limbs of the Z-plasty, with longer limbs giving a greater net gain. In addition, a single large Z-plasty is more effective than multiple smaller Z-plasties whose total limb measurements match the single Z-plasty. The location of the regional direct cutaneous arteries should be considered and avoided.

**6.3.6. Rotation flaps**

**Definition**

A rotation flap is an arc of skin which shares a common border with a triangular defect.

**Types**

• Single flap
• 2 paired flaps for a larger triangle (similar to a H-plasty)
• 2 paired opposite flaps for rectangular defects (“bow tie” closure)

**Use & principles**

If planned with care, no secondary donor site defect is created. Skin for closure is provided by a combination of stretching (advancement) and moving adjacent skin (transposition). This flap has no real advantage over a transposition flap, but is useful for the local closure of triangular defects or defects where the wound tension varies along the defect.

**Design & technique**

The length of the arc of the incision required is approximately 4 times the length required to rotate the flap to cover the defect. In practice, the incision is developed progressively, with undermining, until
the flap covers the defect without tension. The radius of curvature of the flap should be chosen with reference to the likely length of the incision to avoid a disproportionately long thin flap.

6.4. Flank folds

6.4.1. Types of flank fold flaps
The loose skin of the axilla and flank fold may be used for reconstruction in these regions. The fold of skin may be left attached to the limb and used for reconstructions of the limb, or may be left attached to the flank and be used for reconstructions of the flank.

6.4.2. Use and principles
The flank folds are regions of skin which permit mobility of the adjacent limb. These skin folds are attached to the trunk medially and laterally, and are attached to the limb medially and laterally.

A rectangular flap is developed by incising any 3 of these 4 aspects of the fold. The flap is then used as a transposition flap within its arc of rotation.

The skin flap may be used as a rotating flap itself, or, alternatively, a rotating flap is developed close to the skin fold and movement of the flap to the recipient wound is facilitated by using the laxity in the redundant skin of the flank fold, which reduces the length of the incisions in the flank fold itself.

Breeds may vary according to how much redundant skin is present in the fold. It should be noted that the proximity of the fold to the limb and the anatomic function of the fold, to allow free movement of the limb, results in tension on the wound when this skin is used for reconstruction.

6.4.3. Forelimb flank fold

Definition & use
The loose skin in the axilla is used as a transposition flap. The size and the length of the flap depend on the conformation of the individual.

Design & technique
The forelimb fold is grasped to determine the amount of free skin available for transposition while still retaining the ability to close the donor site without tension. Incisions are made along 3 aspects of the rectangle and the resulting flap is used for reconstruction. A cranially based, horizontal flap involving the forelimb fold is essentially an axial pattern flap based on the lateral thoracic artery, which will improve its viability.

6.4.4. Hindlimb flank fold

Definition & use
The loose skin in the hindlimb flank fold is used as a transposition flap. The size and the length of the flap depend on the conformation of the individual.
Design & technique
The hindlimb fold is grasped to determine the amount of free skin available for transposition while still retaining the ability to close the donor site without tension. Incisions are made along 3 aspects of the rectangle and the resulting flap is used for reconstruction. A dorsally based, vertical flap involving the hindlimb flank fold is essentially a restricted axial pattern flap based on the ventral branch of the deep circumflex iliac artery, which will improve its viability.

7. Distant flaps

7.1. Distant skin flaps - General principles

7.1.1. Definition & types
These are random-pattern subdermal plexus flaps that are elevated from skin located at some distance from the wound to be closed. These consist of:
- Direct flaps: the flap is elevated and the primary wound is approximated to the flap
- Indirect flaps: the flap is elevated and the flap is approximated to the primary wound

7.1.3. Use
These flaps are indicated primarily for defects on the distal limbs where other techniques cannot be used. The choice for closing such wounds is often a choice between the use of free skin grafts and distant flaps. The management of the animal with a distant flap may prolonged and more involved, but the surgical technique is easier and the cosmetic appearance and the survival of the new skin may be better.

7.2. Distant direct skin flaps

Definition
A skin flap is elevated from a region of the body distant to the wound and the defect to be closed is physically moved to the flap.

Types
Two basic types are used:
- Single pedicle flap: a single pedicle like a hinge is used
- Bipedicle flap: a bipedicle flap like a pouch is used

Use & principles
The main indications are for defects on the distal limbs and on the pinna. The flap is created on the flank, or neck for the pinna, and the limb with the defect is approximated to the flap. The flap is sutured to the limb and left until the recipient bed is capable of supporting the flap. The pedicle is then divided and the limb is returned to the normal position.
This technique is time-consuming and relatively expensive. If the pedicle is divided in 2 or 3 stages, then 3 or 4 surgeries are required. Some animals cannot tolerate the immobilisation of the limb close to the flank because of orthopaedic disease in the affected limb or the other limbs, or because of their temperament. Muscle atrophy and joint stiffness, with poor-post-operative function may accompany prolonged immobilisation. The appearance of the skin and hair reflects the donor site and the skin is often thicker and the flap more bulky, because of extra subcutaneous fat, than the adjacent skin. This flap is less suited to poorly vascularised wounds, because the pedicle will eventually need to be divided and wounds following tumour excision because of the risk of implanting tumour cells at the donor site. Cats seem to tolerate this procedure better than dogs because of their small size, flexible limbs and ample loose skin. This procedure is not suited to closure of defects created following tumour excision if there is any concern about incomplete excision, as this risks implantation of tumour cells into the donor site.

**Design & technique**

The limb is approximated to the flank in a comfortable position without excessive flexion or extension of the joints. The limb will naturally rotate externally. The region of skin on the flank adjacent to the primary wound is identified. A flap is then created on the flank. The craniocaudal width of the flap matches the proximodistal length of the primary wound and the dorsoventral length of the flap matches the craniocaudal width of the primary wound.

A single pedicle flap is used for defects on the lateral aspect of the wound. A dorsally or ventrally based flap may be used. A bipedicle flap may be used if a single pedicle would be too long. The flap is sutured to the edges of the primary wound. A few larger retention sutures are placed to anchor the limb to the flank. The limb is then bandaged to the flank to immobilise it. The bandage is changed every 2 – 3 days as required.

The pedicle is subject to staged division post-operatively. The pedicle may be divided in 2 or 3 stages, approximately 2 – 3 days apart, starting at 10 - 14 days post-operatively. When the pedicle is finally divided, the donor wound is sutured to the primary wound and the donor site is closed. A portion of the donor site will have been open during the time the pedicle has been maintained and it may be necessary to excise granulation tissue to close the donor site.

### 7.3. Distant indirect flaps

**Definition**

A skin flap is elevated from a region of the body distant to the wound and then the flap is physically moved to the wound, while still retaining a vascular pedicle attachment to the body.

**Types**

These flaps may be raised at the first surgery and then transferred to the primary wound at the time of division of the first pedicle, or after multiple episodes of pedicle division and flap movement, depending on the location of the flap with respect to the primary wound.
Use & principles

The main indications are for wounds on the distal limbs which are not amenable to closure with any other technique or where there is no immediate need to close the site. A bipedicle flap is created, formed into a tube and left in situ. After an appropriate delay of 2 – 3 weeks, one pedicle is divided and the flap is moved closer to the wound. Flap movement may be delayed further if there is evidence of flap ischaemia.

Three methods of moving the flap towards the wound are described:

- **Tumbling**: one pedicle moved over the top of the other pedicle
- **Waltzing**: one pedicle moved parallel to the other pedicle
- **Caterpillar**: one pedicle advanced to adjacent to the other pedicle

This technique is extremely time consuming and expensive because of the number of surgeries required. Staged division of each pedicle using 2 surgeries 2 – 3 days apart will reduce the risk of ischaemia, but increases the number of surgeries. The flap will shrink with time because of a loss of elasticity and increase in fibrous tissue and a flap approximately 2 – 3 cm larger than required should be elevated initially. Long flaps may need to retain a central pedicle during their first elevation to prevent ischaemia of the central portion. The flap should be wide enough to be sutured into a tube. At each step, partial flap necrosis is possible because of an ineffective delay period, accidental kinking or twisting of the pedicle, trauma or infection.

Design & technique

The flap should be elevated as close to the recipient site as possible to minimise the delay and the number of surgeries between flap elevation and closure of the primary wound. A donor site with sufficient elastic skin is chosen. The flap is elevated and tubed. The donor site is closed primarily, although wide flaps may require the use of an advancement flap from one edge (Bunnell method). Once the flap is close to the primary wound, it is used to cover the defect. The other vascular pedicle may then be divided once the primary wound has revascularised the flap, or may be left as a tubed pedicle if further surgery to the region of the wound is anticipated, e.g. wound dehiscence or tumour recurrence.