# WOUND COVERAGE TECHNIQUES

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Open wounds must be provided with coverage. There are an ever-increasing number of coverage techniques available. These include direct closure, skin grafting, flaps (including musculocutaneous and free flaps), artificial skin, cultured cells, amnion, and xenografts. Amnion, artificial skin, and xenografts provide temporary coverage. Skin grafts, flaps, and cultured cells provide permanent coverage.

Skin is mans greatest protection against the bacterial environment. Krizek and Robson have demonstrated that the presence of bacterial growth in a wound is less important as a predictor of infection than is the level of bacterial contamination (1).

They demonstrated that the presence of $10^5$ bacteria is a significant level of bacterial contamination indicative of infection. Temporary wound coverage functions to reduce the level of bacterial contamination and allow host defenses to act more effectively. Reduction of the level of bacterial contamination through proper local wound care is vital before permanent coverage of the wound with a graft or flap. In one study of 50 open wounds judged ready for skin grafting by clinical appearance, the graft success was 94% in those wounds with less than $10^5$ bacteria per gram of tissue and only 19% in those wounds with more than $10^5$ bacteria per gram of tissue (2). Proper local care, including mechanical and surgical debridement, topical medicaments (antibiotics, enzymatic agents), and appropriate dressing materials, is the first step in achieving wound closure. Krizek and Robson's technique of quantitative bacteriology provides the surgeon with a more objective measure of when a wound is ready for coverage, rather than the subjective measure of clinical wound appearance (1).

In addition to the amount of bacteria present in a wound, the type of bacteria that is present is also important. Two organisms particularly destructive to a graft are: *Streptococcus pyogenes* and *Pseudomonas pyocyanea* (3). Systemic antibiotic therapy may be appropriate in certain situations, however, local care of the wound is far more important in eliminating local infection. Once a wound is clean, free of infection and necrotic material, and possessing a good base of granulation tissue, it should be grafted without delay.

## Skin Flaps

Skin flaps are distinct from skin grafts because they retain their vascular attachments including arterial, capillary, and venous structures. The mainstay of skin coverage continues to be skin grafting because of its simplicity and its reduced morbidity compared to flaps. However, in many situations a graft does not provide adequate coverage. Over the past decade advances in microsurgical techniques have led to the development and refinement of the free flap which has opened new horizons in wound coverage.

Specific indications for skin flaps include the following:

1. coverage of areas with poor vascularity (e.g. bare bone or tendon)
2. reconstruction for full thickness
3. padding over bony prominences
4. coverage of areas requiring operation at a later date, and
5. restoration of sensation to an area may be possible if a flap is transferred with its nerve supply.

The word "flap" refers to a tongue of tissue, whereas the word "pedicle" refers only to the base or stem of the flap. The term "pedicle flap" is redundant (1). Rotation and transposition refer to specific types of flaps and should not be used as general adjectives.

### Local Flaps

Local flaps are of two basic types: flaps that rotate about a pivot point (rotation, transposition, and interpolation flaps) and advancement flaps (V-Y, Y-V, single and bipedicle advancement).

Rotation flaps are semicircular flaps that rotate about a pivot point to resurface an adjacent defect. The donor site defect can be closed directly with suture or by a skin graft (partial or full thickness). The ideal shape of the rotation flap is a half circle. The larger the circle of the flap,

the less tension there is at any particular point on the flap.

When excessive tension is present it usually occurs at the pivot point. This can be alleviated by using a back-cut or excising a Burow's triangle. A back-cut is an incision placed on the diameter line of the half circle adjacent to the pivot point. This back-cut releases tension for closure of the flap over the primary defect, but creates a secondary defect that must be closed either by direct suture or skin grafting. Tension can also be released by excising a triangle of skin adjacent to the pivot point (the Burow's triangle). A dog-ear is often created at the apex of the triangulated defect. Excision of the dog-ear is usually done at a later date so that the blood supply of the flap is not jeopardized.

A transposition flap is usually a rectangular or square flap that rotates about a pivot point to cover an adjacent defect. The major difference between the rotation flap and the transposition flap is that the transposition flap movement occurs mainly in lateral direction as opposed to the movement about an arc that occurs with the rotation flap. It is quite common for a particular flap to possess elements of both rotation and transposition, in which case the flap is named based on the predominant motion (4).

The ideal length to breadth ratio is variable depending on the location of the flap, but in the lower extremity, the ratio should probably not exceed 1:1. This aids the vascular supply to the flap by providing adequate pedicle width for entrance of sufficient vessels from the dermal-subdermal plexus. As in some other local flaps, the defect must be triangulated first in order to allow for proper rotation of the flap. The flap is designed longer than the adjacent defect in order to prevent excessive tension. Tension can be released by means of the back-cut or the Burow's triangle. The donor site (or secondary defect) can be closed by direct closure, skin grafting, or by a secondary flap from adjacent lax skin (4). An example of this type of flap is the bilobed flap. Another example of the transposition flap is the Limberg flap for closure of a rhomboid defect.

Advancement flaps are moved directly forward to cover a defect without any rotation or lateral movement. The single pedicle advancement flap is a square or rectangular shaped flap that is stretched forward. The flap is advanced by making use of the skin's elasticity. Tension occurs at the base of the flap and can be relieved by excising Burow's triangle or utilizing back-cuts. The tension created at the base limits this technique to coverage of small areas. Elongation can also be aided by utilizing a Z-plasty on each side of the base of the flap. Each of these techniques acts to relieve tension in a longitudinal direction while exaggerating transverse tension across the base. A bipedicle advancement flap can also be used. This is created by performing a longitudinal incision parallel to the longitudinal axis of the defect. The interposed skin is then undermined and advanced laterally over the primary defect. The secondary defect can be covered with a skin graft. Other types of advancement flaps include the V to Y and Y to V advancement flaps.

## Distant Flaps

In addition to local flaps, skin coverage can be obtained from a site distant from the defect. In the lower extremity, indirect distant flaps by means of a carrier are seldom used. Direct flaps in the lower extremity are primarily transferred from the opposite extremity. The first step in the technique for this cross-leg flap consists of raising the flap on the donor leg. This creates a donor defect which can be covered with a split thickness skin graft at the time of the initial surgery. The raised flap is then applied to the recipient site and sutured in place with a hinged edge still attached to the donor leg for its blood supply. The two limbs must be immobilized (casting, pins in plaster, external fixation) until the flap is ready for division and insetting into the recipient site (4, 5). In older patients this can result in serious joint stiffness. At 14-21 days the flap can be separated from the donor leg and the hinged edge sutured into place at the recipient site.

Taylor and Hopson have described a cross-foot flap that can be used to cover a heel defect with a flap from the contralateral medial arch (6). Disadvantages of cross leg flaps include the prolonged hospitalization and immobilization which produces significant morbidity, and the insensitive and relatively avascular nature of the flaps. Cross-extremity flaps are less frequently used now because of advances in the techniques of muscle flaps, myocutaneous flaps, and free flaps.

The free flap is a composite of tissue composed of skin and subcutaneous tissue transferred in one stage to a distant site with a blood supply that is restored by microvascular anastomosis (7). Other tissues such as bone and muscle may be transferred at the same time. The transfer of muscles has been suggested as a treatment for chronic osteomyelitis of the lower extremity (8). The concept behind this is to provide greater vascularity to the infected area than would be possible with local flaps. The technique is a valuable adjunct to therapy of this very difficult problem and must be combined with standard principles such as debridement of infected tissue and perioperative antibiotics (8). The technique may also be used for the management of acute bone exposure wounds in order to reduce the incidence of bone

infections (9, 10).

Common donor sites for free flap transfers include the groin (11), dorsalis pedis territory of the first web space (12), latissimus dorsi myocutaneous flap (13), and the tensor fascia lata (14).

The advantages to this technique include the one stage nature of the procedure, excellent vascularity provided to the recipient area, full thickness coverage provided to the area including muscle and bone if needed and reduced hospitalization time compared to other techniques for similar indications. The disadvantages include the technical difficulty of the procedure, prolonged anesthesia time, excessive bulk to certain flaps, and the risk of loss of the flap. Venous or arterial thrombosis is a major risk (15). The procedure is best performed at those centers that perform microsurgery on a regular basis.

Specific indications in the foot include trauma subsequent to motor vehicle accident and high velocity gunshot wounds with significant soft tissue loss (16, 17). Often, the only alternative for these patients is amputation. The free groin flap is valuable in areas where coverage is needed without excessive bulk,

## Muscle and Myocutaneous Flaps

Muscle and myocutaneous flaps can provide bulk, padding, skin coverage, and vascularity to an area. The decision to utilize muscle flaps should be made based on knowledge of the anatomy, function, and reliability of the muscle. The preoperative evaluation must include the viable length of the muscle on the dominant vascular pedicle, the point and arc of rotation of the flap, the effect of loss of function of the muscle, and the possible size of the cutaneous segment to be transferred with the muscle (18). In general, muscles can support a cutaneous segment 50% larger than the size of the muscle, although this must be individualized.

Muscle flaps can be utilized in both the leg and foot. The leg can be conveniently divided into three regions where muscle flap use will vary depending upon the accessible muscles. In the upper third of the leg muscle coverage can be obtained with the gastrocnemius or soleus muscles. The middle third of the leg can best be covered with the soleus although the gastrocnemius, flexor digitorum longus, and tibialis anterior muscle flaps can also be used for certain indications in this area. In the lower third of the leg local muscle flaps include the soleus muscle with skin graft and the peroneus brevis. Distally based flaps of soleus, extensor digitorum longus and extensor hallucis longus can be utilized when minor vascular pedicles are intact (19-23).

In the foot coverage of the heel can be obtained with the flexor digitorum brevis muscle and a skin graft (24, 25). The flexor digitorum brevis is supplied by both the medial and lateral plantar arteries with the dominant supply from the lateral plantar artery. The flap is approached through a midline plantar incision with superficial fascia reflected off of the plantar fascia and retracted medially and laterally. The four tendons of the muscle are divided distally and the muscle reflected back on itself. When the defect is more proximal, the origin of the muscle can be detached off the calcaneus to allow for more mobility of the flap (26).

The abductor hallucis can be used for coverage below the medial malleolus. The muscle is supplied by proximal and distal branches off of the medial plantar artery. The tendon can be detached distally and reflected over itself to cover defect along the medial arch below the medial malleolus. Division of the distal branches of the medial plantar artery supply to the muscle will allow greater proximal coverage (26).

The abductor digiti minimi can be used for coverage of defects below the lateral malleolus. This small muscle is supplied by the lateral neurovascular bundle. Division of the distal vascular pedicles allows for greater proximal mobility (26).

## Summary

Complex wound repair can be accomplished by a number of different methods. The simplest technique should be utilized whenever possible.

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