ABC of wound healing Reconstructive surgery

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Many surgical options are available to a reconstructive surgeon when faced with a difficult wound. However, any decision about management should be holistic and take into account factors such as the occupational circumstances of the patient and likely period of time off work, comorbidity, likelihood of success, donor morbidity, functional outcome, and the risks of surgery and anaesthesia. The basic principles of wound management apply to all wounds.

The “reconstructive ladder”

Reconstructive surgeons use the concept of a “reconstructive ladder”—the more problematic the wound, the higher up the ladder the surgeon has to climb. Simple wounds may be closed by primary suturing, sometimes in the primary care setting. But others may require complex reconstruction, including free tissue transfer, in hospital.

All traumatic wounds should undergo debridement and thorough irrigation before primary closure. The aim of debridement is to remove all potentially contaminated and devitalised tissue along with foreign material. Primary suture may not be indicated in heavily contaminated wounds, where the risk of infection is high. In such cases the wound should be debrided, with “delayed closure” carried out later. Occasionally, wounds may be allowed to heal by secondary intention, where areas of skin loss are initially replaced by granulation tissue. The skin defect continues to heal as a result of proliferation or migration of epidermal cells within and around the wound and by contraction of the wound by specialised cells (myofibroblasts) within the granulation tissue. Healing by secondary intention is slow and may lead to contractures, scarring, and restriction of movements.

Where skin defects are too large for skin apposition, and healing by secondary intention is inappropriate, skin grafts may be used. Free skin grafts are taken from another part of the body and rely on revascularisation from a healthy, well vascularised wound bed. Grafts will not be successful on non-vascularised beds, such as exposed bone or tendon.

Split skin grafts consist of the epidermis and a variable amount of dermis. They are usually harvested from the thigh using a specially designed knife or powered dermatome. The donor area will heal within 10–14 days from remaining dermal adnexal structures. Such grafts are the mainstay of treatment of large wounds such as burns. Full thickness grafts consist of the epidermis and dermis and offer several advantages, but are size limited as the donor area must be directly closed.

Expansion of local skin using subcutaneous tissue expanders is a method of increasing the amount of skin locally available. A tissue expander is placed beneath the skin and inflated at weekly intervals by injecting saline through a remote port. The overlying tissue expands in response to mechanical force. Epidermal thickness increases as a result of cellular hyperplasia. The dermis also undergoes increased fibroplasia, with realignment of collagen fibres and disruption of elastic fibres. This also results, however, in a reduction in dermal thickness and separation of dermal appendages, such as hair follicles.

This is the eighth in a series of 12 articles

The surgical management of problem wounds generally aims to obtain rapid wound closure with the simplest method and with minimal compromise of cosmesis and function

The “reconstructive ladder” is used by reconstructive surgeons to assess the complexity of treatment required

A finger injury is irrigated with saline before debridement and closure

Harvesting a split thickness skin graft using a hand held knife

A tissue expander has been used to expand the right side of the scalp to reconstruct the wound left after excision of a congenital melanocytic naevus

Many wounds, such as fracture sites and exposed bone or tendon, are not suitable for grafting, and techniques further up the reconstructive ladder, such as a flap reconstruction, must be used. A flap is a unit of tissue that can be moved to cover a wound while surviving on its own vascular supply. Random pattern flaps rely on random cutaneous vessels for their blood supply.

Greater lengths of flap can be used by including the underlying deep fascia and also by including a perforating blood vessel in the base of the flap. In some circumstances better cosmesis may be obtained by raising the flap as fascia only, leaving the overlying skin behind. "Islanding" a flap on its vascular pedicle allows even greater pedicle length and thus greater mobility and versatility. Occasionally no options are available for local wound cover, and tissue has to be harvested from elsewhere around the body by using microvascular techniques. This transfer of tissue, known as a free flap, represents the top rung of the reconstructive ladder. Any tissue that can be isolated on a suitable vascular pedicle can be used, and it may include muscle, skin, fascia, fat, nerve, and bone.

Left: Compound tibial fracture. Right: Wound closure of the fracture using a free latissimus dorsi muscle flap covered with a split thickness skin graft

Specific wounds

Pressure ulcers

When considering surgery for pressure ulcers, bear in mind that the wound will recur if the original precipitant is still present. Surgical intervention may sometimes be required, once intrinsic and extrinsic factors have been resolved. Some units have "outreach" pressure ulcer teams who will give treatment and advice both in the community and on the wards. Surgery should be a last resort and would consist of an "oncological" debridement of the ulcer (including any areas of osteomyelitis) and excision of bony prominences. Direct closure is usually not possible, and a local closure using a fasciocutaneous or myocutaneous flap is usually necessary.

Necrotising infections

Acute infections such as necrotising fasciitis can cause rapid tissue loss in a very short time. They have polymicrobial aetiology, and the classic Lancefield group A β haemolytic streptococci may be present in only 15% of cases. After adequate resuscitation, appropriate antibiotics and prompt surgical debridement of affected areas may be life saving, and the patient would need a period of intensive support. Significant tissue destruction can occur in minutes, highlighting the importance of rapid debridement, and subsequently large body surface areas may require surgical reconstruction, most often with split skin grafts. Flap coverage may occasionally be needed when the bed is not suitable for a graft.

Arterial ulcers

Peripheral vascular disease can be a primary cause of ulceration and poor wound healing and is often a contributory reason for poor healing of wounds from other causes. Bypass grafting or angioplasty to improve arterial input to the distal limb can be curative in itself or can be done to enable other forms of

Left to right: Excision of a tumour has left a defect on the nasal tip (the flaps have been raised but not transposed); the flap is transposed into the defect, and the adjacent flap is transposed into the donor area; final result. This procedure is an example of a random patterned flap

Top: Defect on the back of the hand showing exposed fractures and destroyed tendons (this is unsuitable for skin grafting). Centre: At reconstruction a distally based adipofascial flap has been raised using the radial artery as a pedicle; the overlying donor skin is closed primarily. Bottom: The flap is inset and covered by a split skin graft

Most wound types outlined in this section are discussed in more detail in previous articles in this series

Left: Chronic trochanteric pressure ulcer excised. Right: Reconstruction using a tensor fascia lata myocutaneous flap

Top: Necrotising fasciitis of the groin after surgical debridement. Bottom: Wound closure with a split thickness skin graft

reconstruction that otherwise would fail (such as grafts or flaps). Other indications for surgery include the debridement of necrotic or infected tissue. In circumstances of chronic non-healing, sepsis, or long term disability, amputation of digits or limbs is often the best solution to enable rapid healing and improve quality of life. With appropriate counselling from the multidisciplinary team (surgeon, prosthetist, specialist nurses, physiotherapist, occupational therapist, and general practitioner), patients can make informed decisions about such treatments. Prosthetists can advise the surgeon on the level of amputation required taking into account the most up to date or suitable artificial aids.

Diabetic foot ulcers

After proximal arterial disease has been excluded, hypertrophic keratinous edges of ulcers are debrided and pressure points "off loaded" (relieved of pressure) by use of appropriate orthoses, although bony prominences and areas of osteomyelitis may need to be excised. If, despite adequate treatment and graft or flap closure, ulceration and infection recurs, amputation may be the best treatment.

Pilonidal sinus and abscess

Chronic sinuses are excised down to the sacral fascia. The wound is allowed to heal by secondary intention or closed with the aid of "Z plasty" (a procedure involving transposition of two interdigitating triangular flaps that elongate and change direction of the common limb of the flap) or a local flap.

Non-melanoma skin cancer

Basal cell carcinoma and squamous cell carcinoma are the two commonest types of skin cancer and are often characterised by ulceration. In addition, squamous cell carcinoma can develop in any chronic wound. Treatment of these lesions requires excision with a suitable margin (typically 3 mm for basal cell and 5 mm for squamous cell carcinoma). Preoperative microbiology testing and perioperative antibiotics are recommended for excision of ulcerated lesions, as such excisions are associated with increased rates of surgical wound infection. Radiotherapy, curettage, cryosurgery, and photodynamic therapy—as well as a number of new topical treatments—may be used in the treatment of basal cell carcinoma, but none of these procedures can provide definitive histology or match adequate surgery in terms of recurrence rates.

Hidradenitis suppurativa

Surgery entails excision of the affected area, leaving a large skin wound. Primary closure of the wound is usually not possible. Healing by secondary intention involves many weeks of dressings and a substantial risk of scar contracture. Skin grafts may be used, but these run the risk of resulting in scar contracture and delayed healing. Flap reconstruction may result in more rapid wound closure and a reduced risk of contracture.

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Venous leg ulcers

- Surgery, if indicated, may include application of split skin graft on to a healthy ulcer bed, pinch grafting (several small islands of epidermis from a healthy donor site applied to the wound bed), and excision of the ulcer and treatment with split skin grafts
- These techniques may enable more rapid healing than dressings and compression alone. However, this is at the cost of a donor site wound, which may be slow to heal because of infection or other comorbidities, such as diabetes
- More complex procedures, such as coverage with a flap, may be required if tendon or bone is exposed. Tissue engineered skin substitutes have been used (see 12th article in this series), but this technique remains an expensive and unconventional treatment

With a diabetic foot ulcer, amputation may be in the form of a ray amputation, or an amputation at the level of forefoot, midfoot, hind foot, or below the knee

Top left: Recurrent pilonidal disease (the patient had had 14 operations); perforator based flap is marked; the circle indicates the site of the perforator. Top right: Defect after excision to sacral fascia. Bottom left: Flap transposed into defect. Bottom right: Disease-free one year after surgery

Defect after hidradenitis excision closed by an islanded V-Y flap based on perforating vessels from the thoracodorsal artery

Further reading

- Hasham S, Matteucci P, Stanley PRW, Hart NB. Necrotising fasciitis. *BMJ* 2005;330:830-3.
- Leaper DJ, Harding KG, eds. *Wounds: biology and management*. Oxford: Oxford University Press, 1998.
- McGregor AD, McGregor IA. *Fundamental techniques of plastic surgery, and their surgical applications*. 10th ed. London: Churchill Livingstone, 2000.
- Téot L, Banwell PE, Ziegler UE, eds. *Surgery in wounds*. Berlin: Springer, 2004.

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