Plastic and Reconstructive Surgery

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MICROVASCULAR SURGERY

History		
1902-3	Carrel and Guthrie Haptner	Successful limb replantation in animals
1963	Che'en <i>et al</i> (China)	First successful arm replantation in man
1966	Tamai (Japan)	First successful digit replantation
1969	Cobbett (England)	First toe/thumb transfer
1971	Buncke (USA)	Free omental transfer with revascularisation to cover scalp defect
1972	Harii (Japan)	First successful free flap transfer (scalp)

In 1902 Carrel and Guthrie reported the successful replantation of amputated limbs in dogs using the type of technique in their anastomosis that microvascular surgeons use today. The introduction of the operating microscope by Nylén in 1921 eventually allowed smaller vessels to be successfully repaired, and in 1963 the first successful replantation of an amputated limb was reported in China. In 1966 Tamai was the first surgeon to replant successfully an amputated thumb; this led to the establishment of what has now become a successful and commonplace emergency operation. At the same time the ability to move composite tissues around the body with reanastomosis of their supplying blood vessels to local blood vessels has revolutionised reconstructive surgery since the first successful free flap transfer in 1972.

Replantation

Patients who sustain traumatic amputations of either the whole or part of a limb should be considered for replantation and referred to a centre with particular experience in this work. Before transfer patients must be thoroughly assessed for other less dramatic injuries and if necessary resuscitated with intravenous fluids. In amputation of an arm or leg the period of ischaemia is critical, and several patients have died from renal failure probably produced by the release of free myoglobin. Digits, however, are less susceptible to ischaemia. Amputated members should be placed in a polythene bag, which can then be immersed in iced water before transfer.

Not all amputated members are suitable for replantation, and the selection should be carefully undertaken by an experienced surgeon. A crush or avulsion type injury makes replantation far less satisfactory than does a straight guillotine type injury. The patient's age is important; far better results are obtained in younger patients. A single amputated digit may not always be replanted provided the rest of the hand has full function, but with an amputated thumb replantation is always attempted as its loss represents a 50% reduction in hand function. The table shows other factors taken into consideration.

Replantation surgery requires a trained team of surgeons, anaesthetists, and nurses and facilities for prolonged rehabilitation. The operation may be performed under either regional block anaesthesia or general anaesthesia.

Criteria for selection
Type of injury
Level of amputation
Number of and the particular digit
Age and coexistent disease
Occupation and patient's wishes
Patient's ability to cooperate with rehabilitation
Length of ischaemia and facilities available

Firstly, the bony skeleton is stabilised and severed tendons repaired. Secondly, blood vessels and nerves are anastomosed and skin cover obtained either by local flaps or skin grafting. Postoperatively the amputated limb requires close monitoring and the vascular anastomosis should be re-explored urgently if any vascular embarrassment occurs. After successful replantation prolonged and intensive rehabilitation is required if the amputated limb is to become of any functional use to the patient, the mere cosmetic survival of an amputated limb no longer being considered to be a success. That these operations are time consuming emergency procedures, expensive in operating time, resources, staff, and, postoperatively, rehabilitation, makes them best suited to centres with suitable resources.

RESULTS OF EMERGENCY REPLANTATION

Arm—The results depend on the initial aetiology of the accident, but generally only a fair result is obtained. Cosmetic appearance is usually excellent, but sensation to the hand is only partially recovered. The return in muscle power is poor except at the elbow joint, and in general patients do not return to their original job if it requires two handed coordination.

Hand—Much better results are obtained with this amputation, and in 60% of cases reasonable hand function is achieved.

Digit—Seventy five per cent of patients obtain excellent results and are able to resume their original work. They may have a range of motion in the distal joints of 60% of normal, and have a complete or near complete recovery of sensation. The main complications of replantation surgery, particularly of the digits, include intolerance of cold or anaesthesia, or both, and stiffness of adjacent joints. Nerve recovery depends on the extent of the injury but is greatly influenced by the patient's age—that is, younger patients obtain better results than older patients.

Other structures may also be replanted—for example, the scalp, which may be avulsed by long hair being caught in rotating machinery. The lip and nose may be traumatically amputated en bloc and have been replanted successfully as have amputated ears. Successful replantation of legs has been reported, but function is poor, and even amputated penises have been successfully replanted. The successful replantation of digits has also permitted the transfer of one or two toes to reconstruct lost thumbs or fingers. Initially the first toe was used, but now more commonly the second toe is transferred. The tissues are moved as a composite unit on the dorsalis pedis artery and accompanying superficial veins together with the digital nerve; these are joined to the appropriate vessels and nerves in the hand. There is minimal functional abnormality in the foot, and the results in the hand from a functional point of view are excellent, particularly in young children.

Free flaps

Dissecting radial forearm flap

The appreciation of the anatomical basis of skin flaps has permitted the successful transfer of skin to distant areas of the body that do not have suitable local flaps. This is achieved by re-establishing their blood supply by anastomosing the artery and vein of their pedicle to a local artery and vein—a so called free flap.

Skin alone may be transferred to reconstruct defects after either a traumatic loss of skin, particularly in the leg, or after excision of tissues for head and neck malignancies. The original flaps used were the groin flap, the deltopectoral flap, and scalp flaps. Skin on the dorsum of the foot based on the dorsalis pedis artery and forearm skin based on the radial artery have more recently been described and have the advantage of permitting the transfer of thin mobile skin, which is of particular advantage in intraoral reconstruction.

In particularly hostile environments, such as follow extensive radiotherapy in the head and neck area or chronic osteomyelitis in the leg, free flaps are transferred based on myocutaneous flaps. Such free flaps include the latissimus dorsi and tensor fascia lata muscles. Muscle is thought to be much more capable of withstanding these hostile environments and overcoming radionecrosis or osteomyelitis.

Radial forearm flap providing scalp cover

Donor sites of more common free flaps

Vascularised fibula graft for pseudarthrosis

The advantages of such free flap techniques are that usually they allow for a one stage operation and in many cases the donor site may be closed primarily or easily hidden from view. The success of such procedures particularly in head and neck reconstruction is at least 90%, comparing very favourably with other types of flaps, particularly with the now almost abandoned tube pedicle.

Because function in many cases is more important than cosmesis both composite flap tissue transfers and specialised tissue transfer have been developed. Composite flaps containing bone, muscle, and overlying skin have been developed for both reconstruction of the jaw and preservation of the leg. The principal ones used are the transfer of iliac crest based on the deep circumflex iliac vessels (the groin flap), the transfer of fibula based on the perineal vessels, and the transfer of part of the radius on the radial forearm flap. Muscle may also be transferred to provide a functional contracting unit, particularly in paralysis of the arm or face. Transfer of muscle obviously requires a successful vascular anastomosis and also reinnervation of the muscle with a local motor nerve. In facial paralysis the operation performed depends on the duration of paralysis. If denervation of the facial muscles has occurred less than one year previously a cross facial nerve anastomosis can be performed using nerve grafts from the sural nerve of the leg as a cable from the facial nerve on the unparalysed side to join with the nerve supplying the paralysed muscle on the affected side. If the paralysis has existed for more than one year these muscles will have wasted and lost their ability to contract. In this case a cross facial nerve graft is combined with a second operation six months later when either the gracilis muscle or pectoralis minor muscle is transferred to the paralysed side of the face and used as motor unit. Its own blood supply is reanastomosed to local blood vessels and its motor nerve joined to the cross facial nerve graft. The quality of the result depends on the nerve anastomoses, but good results have been achieved in younger patients producing bilateral symmetrical facial movement to the lower face.

The microvascular transfer of free tissues has been used on several other organs and structures including joints, nerve, testis, and bowel. In the case of the bowel, after ablative head and neck surgery, large defects in the pharyngeal and cervical oesophagus may be replaced by a segment of jejunum, which can be revascularised by anastomosing its mesenteric vessels to local vessels in the neck. The jejunum is preferred for this procedure because the mesentery is thinner, allowing easier identification of the pedicle compared with the ileum. The colon has also been used in a similar fashion as a conduit either as a free flap or as a pedicle flap and reinforcing its blood supply by anastomosing the marginal artery and vein to vessels in the neck. It does, however, present problems with the discrepancy in size. The transfer of bowel in the way described above is a safe operation with a 90% success rate and the advantage of being a one stage transfer with an independent blood supply. Its principal disadvantage is that secretions can cause an overspill into the bronchial tree, and in a sick patient laparotomy with bowel anastomosis may have its own complications.

Although microvascular procedures may in many ways still be considered to be in their infancy and undoubtedly take longer to perform, they have the advantage of being in general one stage procedures. With the use of larger vessels both on the recipient flap and donor site transfers have become far quicker. As a result success rates of up to 90% have been reported, comparing very favourably with other methods of reconstruction. Now that small vessels can be successfully joined together, and once tissue rejection has been solved, composite tissue transfers from cadavers will permit unprecedented possibilities for reconstruction.

Hand replantation courtesy of P Townsend.

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