The operative mortality for the colon (10.1%) was slightly higher than that for the rectum (7.6%). Amongst the causes of post-operative death, pulmonary embolus and peritonitis were equally the most frequent.

The pathology of local and general recurrence is considered.

The overall five-year survival rate is slightly higher for the rectum (33%) than for the colon (31%). A comparison is made between the results of anterior resection and combined excision and their significance discussed.

Further improvements in surgical technique will still further reduce mortality, but when age, the severity of the necessary operations, and the causes of death are considered it is certain that the best reduction would be achieved by earlier diagnosis.

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RECONSTRUCTIVE SURGERY OF THE HAND, WITH SPECIAL REFERENCE TO SKIN COVER*

BY

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This paper sets out to establish the principles of reconstructive surgery of the hand, on an understanding of the normal functional anatomy and the modified anatomy following the effects of injury. The first principle is the preservation of function, the second is the preservation of tissue. The methods used for repair following injury, here presented, incorporate these two principles.

Functional Anatomy

The power of grip is greatest on the radial side of the hand, the ulnar side being mainly concerned with the interpretation of stresses and strain by virtue of its highly sensitive hypothenar surface. The thumb and little finger have a greater range of movement than the other digits and, acting together, produce the cupping of the palm in flexion and the flat palm in extension. They can compensate for damage to joints and tendons and adapt themselves to their disability, in striking contrast to the index, middle, and ring fingers. This is due, in the thumb, to the fact that the thenar muscles can partly flex and extend the terminal phalanx when the long flexor or extensor is divided and the short abductor can to some extent compensate for the loss of the long abductor.

In the little finger, ankylosis of the metacarpo-phalangeal joint can be compensated for, by shortening in this area, thus allowing the pulp of the terminal phalanx to reach the palm. Ankylosis of the proximal inter-

phalangeal joint in 50 degrees of flexion will allow the pulp of the terminal phalanx to reach the palm and, in extension, bring it within the plane of extension of the fingers by an increase in the range of extension and flexion of the metacarpo-phalangeal joint assisted by the mobility of the fifth metacarpal. This degree of

FIG. 1

compensation cannot be achieved in ankylosis of the proximal interphalangeal joint of the index, middle, or ring fingers.

When the terminal phalanx of the little finger has been amputated the stump can be flexed into the palm by an increase in the range of flexion of the metacarpo-phalangeal and the carpo-metacarpal joints, producing little or no dysfunction in the stability or power of grip. In the case of the thumb, ankylosis of the metacarpo-phalangeal joint can be compensated for by an increased range of movement in the carpo-metacarpal joint.

The preservation of the thumb and the little finger is of primary importance to the damaged hand, and the so-called cosmetic amputation of the little finger should be avoided if the breadth and mobility of the palm are to be preserved.

Planes of Flexion and Extension

In full extension the flat surface provided by the palm and fingers is an essential functional requirement, and a finger-tip which transgresses this plane by a fixed flexion deformity should be shortened (see Fig. 1).

In flexion the heads of the metacarpals and phalanges produce a series of parallel transverse planes, and any phalanx which lies out of alignment presents a disability (see Fig. 2). This may be corrected by mobilization of the joint involved, re-education to correct a defence mechanism, or shortening. Patients often hyperextend a finger as a defence to bring the stump out of the range of function.

When a short middle phalanx does not flex it is subject to trauma, as it does not lie in the transverse plane of the proximal phalangeal heads when the fingers are in full flexion. It should therefore be shortened to lie in this plane.

FIG. 2

Physiological Position of Rest and After-care

After operation the hand should be immobilized in the position of rest. The wrist is held in 30 degrees of extension and slight ulnar deviation, and the fingers should be immobilized in the position they adopt with this degree of extension. This varies with the age of the patient. In young children, with the wrist extended, the little finger is flexed

*Lecture given to the Royal College of Surgeons of Edinburgh.

into the palm and the index finger is almost fully extended, the middle and ring fingers adopting an intermediate position between the two. The thumb is abducted and opposed. With increasing age the gradation is less pronounced, and the exact functional position can be seen by placing the normal wrist in 30 degrees of extension and observing the position into which the fingers fall. This is best demonstrated with the patient fully anaesthetized.

Control of oedema is achieved by bandaging the whole hand and fingers firmly, but not tightly. Lateral compression will obstruct the venous and lymphatic returns and lead to post-operative fibrosis. Prevention of oedema should be by elevation until the post-operative reaction has subsided, after which full active movements to the fingers, hand, wrist, and upper limb should be instituted.

Amputations

In traumatic amputation of the fingers the provision of skin cover by grafting should be an accepted practice in cases where a reduction in length to provide skin flaps would render the digit functionally useless. The thumb and little finger, however, adapt themselves functionally to any length, and further shortening by surgery after injury is never justified in the presence of an adequate blood supply, as compensatory mechanisms are available to offset any functional disability. Although preservation of the length of the digit with minimal reduction of bone and soft tissue and coverage of raw areas by grafting should be the treatment of choice, it becomes necessary to shorten an index, middle, or ring finger when its length does not conform to the normal transverse planes of flexion and extension of all the fingers.

Skin Cover

In choosing the method of skin replacement, first consideration should be given to the free graft. In free grafting the choice lies between the split-skin graft, the whole-thickness graft, and the pinch graft. A free graft is said to survive by plasmatic circulation for the first 48 hours and thereafter is invaded by capillaries. By the fourth day the capillary circulation is said to be established. The thinner the graft the longer it will survive on a plasmatic circulation, and the split-skin graft is specifically the graft of choice over bone where periosteum or cancellous bone is exposed. No free graft, however, will survive on exposed

FIG. 3

cortical bone. The thicker grafts retain their substance to some extent and are preferable over weight-bearing surfaces such as the pulp of the finger.

Finger-tip loss (see Fig. 3) may be classified into: group 1, soft-tissue loss only; group 2, soft-tissue and bone loss. Group 2 is subdivided into tangential injuries of the dorsum, loss of less than one-third of the terminal phalanx, and loss of more than one-third of the terminal phalanx.

In group 1 cases the object is to replace not only the lost skin but also the underlying substance, and for this the thicker type of free graft is chosen, preferably the pinch graft.

In group 2 tangential injuries of the dorsum, remove the nail-bed and expose bone. If the cortex is exposed it should

be removed to provide a cancellous base for the graft. The graft of choice is a thin split-skin graft; because it survives better over periosteum or bone, and as the graft will replace the lost nail-bed, bulk should be avoided, to allow the nail to grow over the graft without deformity. In loss of less than one-third of the terminal phalanx the raw area should be covered by a pinch or Wolfe graft to replace the lost bulk, unless the tissue loss is greater than the bone loss, in which case the area should be covered by a viable skin flap. Loss of more than one-third of the terminal phalanx will deprive the growing nail of adequate support and thus lead to a nail both deformed and functionally useless. This type of case requires a complete removal of the nail-bed, and the raw area should be covered with a viable skin flap, although a tangential loss can be adequately dealt with by a split-skin graft.

In cases where several finger-tips are injured it may be necessary to free-graft one or more and apply viable skin flaps to the others. An example of this is a patient who sustained a tangential injury to the dorsum of the index and little fingers with loss of less than one-third of the terminal phalanges, and a guillotine amputation of the middle and ring fingers with loss of more than one-third of the terminal phalanges. The raw areas on the index and little fingers were covered with split-skin grafts, and the middle and ring fingers with viable skin flaps.

Where full-thickness skin cover is indicated the choice of donor site is roughly dependent on the age and the sex of the patient, with a preference for a texture of skin resembling the recipient area. The more commonly used donor sites are thenar, acromio-pectoral, opposite arm, submammary, and abdominal.

Thenar Flap.—The skin of the palm closely resembles that of the finger, and this type of flap will give an excellent weight-bearing surface. One or two finger-tips may be covered by this method, and the patient may be treated as an out-patient during the 14 days prior to detachment. Its usefulness, however, is limited by certain specific contraindications, and it may be mentioned here that a painful donor site on the palm is not one of them. The contraindications are: (1) age—in patients past middle age the interphalangeal joints tend to remain stiff after immobilization of the digit in a position of acute flexion for 14 days; (2) arthritis of the digital joints; (3) the short spatulate hand; and (4) where the skin of the hand is very thick, as seen in the manual labourer. Fig. 4 shows the elevation of the flap, the length of which should not exceed the width; the lining of the flap; the cover of the donor area with a free graft; and the inset of the flap. Two points should be taken into consideration: firstly, the fingers in flexion are directed towards the tubercle of the scaphoid, and therefore the flap should be elevated in a slightly oblique direction to the transverse plane of the palm. Secondly, not less than 50% of the flap should be inset, to insure an adequate blood supply. When applying fixation, wool should be placed between the finger and the palm, and bandaging should avoid pressure, otherwise the finger-tip may be pressed into the donor area and possibly damage the underlying nerve (personal communication of a reported case).

Cross-Arm Flap.—This site can be used to cover the finger-tips where one or four fingers are involved. The disadvantages are that the patient is unable to care for himself, and the donor area lies on a surface of the forearm frequently exposed. The principles of the operation are similar to the thenar flap, and Fig. 5 shows the stages of the operation.

Acromio-pectoral and Submammary Flaps.—The principles of the operation are as already described. The position is comfortable, and the patient need not stay in hospital. Care should be taken to keep the shoulder mobilized. The skin texture, however, is not ideal.

Abdominal Flap.—This site is used where either large or multiple flaps are required. In the hand, abdominal flaps

are used when complete skin cover is required for the dorsum or for the palm. The skin of the abdomen is often used in young children for cover of the fingers: because of the extreme difficulty of effecting immobilization it is advisable to raise a much larger flap than is necessary and partially tube it. This will allow of movement of the hand on the abdomen and reduce the risk of traction on the recipient area.

Thumb.—Skin cover for the thumb can be obtained by any of the methods previously described, with the exception of the thenar flap. Local flaps can be used to cover the terminal phalanx, a similar method to that used in cross-finger flaps, described below. In the same way a skin flap from the dorsum of the hand can be used to cover the flexor aspect of the proximal phalanx. When possible, it is preferable to use local skin flaps, as the skin is of good quality for weight-bearing surface on the hand, and it develops a higher degree of sensation than skin transported from a distance. An example of this is a patient who lost the skin from the flexor aspect of his thumb, exposing tendon and necessitating full-thickness skin cover. The defect was closed by a flap elevated from the dorsum of the hand, turned through 90 degrees, and inset into the flexor aspect of the thumb. The flap was detached after 14 days.

Middle and Proximal Phalanges of the Fingers.—Skin loss over the flexor aspects of the middle and proximal phalanges of the fingers may be repaired by flaps from the abdomen, chest, or arm; but, ideally, cover is provided from the dorsum of the contiguous finger by the cross-finger flap method. Fig. 6 shows the stages of the operation. An example is the case of a patient who burned her right middle finger. The area of skin loss exposing the long flexor tendon and the digital nerve was covered with a flap raised from the dorsum of the ring finger and turned through 180 degrees. The donor area on the ring finger was covered with a Wolfe graft from the left breast. It is possible to inset this flap only when the fingers are flexed owing to the disparity in length of any two fingers.

Degloving Injury of the Palm and Dorsum

This type of injury, which is not uncommon in industrial accidents, is a shearing effect often caused by catching the hand in rollers or in a press. The entire dorsum, palm, or both surfaces may be turned back on a distally based flap. Should this flap carry with it the venous plexus, as it often does, then it will become cyanosed within a few hours and the arterial blood supply will inevitably fail. At the time of injury the flap may appear viable, as in fact it is, with a good colour and a freely bleeding edge. An immediate decision to excise the flap and cover the raw area with a graft or a flap, according to whether the tendons are exposed or not, is not an easy one to make. Most surgeons will stitch the flap back and review in 24 hours, and exposed tendons will not suffer from this delay should the flap fail to survive. It should be emphasized, however,

that undue delay is unwarrantable, as infection is common under necrotic skin, and this not only jeopardizes the survival of deep structures but adds greatly to the post-traumatic fibrosis.

The next case is an example of the degloving type of injury involving the palm of the hand. This patient caught his hand in rollers, and the whole palm from the wrist crease to the base of the fingers had been turned back on a distally based flap. This flap was of good colour and had a freely bleeding edge. It was stitched back. Twenty-four hours later the flap was cyanosed, and it was therefore removed, the defect being covered by an abdominal flap. Where whole-thickness skin cover by a viable flap method is required, whether for the dorsum or the palm, the donor site of choice is the abdomen. An alternative procedure rarely used for the dorsum of the hand is the tunnel flap (see Fig. 7). This method is mentioned merely to discard it. It has no advantages over the single-based flap and has many disadvantages. With the patient fully anaesthetized the flap will appear to accommodate itself to the defect by compression of the abdominal wall. When tone recovers, however, the flap becomes taut over the hand and the tension is taken on the suture lines with subsequent necrosis, spreading towards the centre of the flap.

Degloving Injuries of the Hand and Fingers

In degloving injuries of the fingers complete replacement with abdominal flaps or tubes cannot be expected to give the patient a normal digit. There is, inevitably, some loss in joint mobility, and the skin covering is a poor substitute for normal hand skin. It does, however, provide the patient with a means to grip and even pick up small objects, and is therefore superior to any other reconstruction. The patient presented under this heading caught his hand in rollers. The dorsum of the hand was degloved and all the fingers stripped of skin cover. The middle and ring fingers were fractured and fit only for amputation. Two flaps were elevated from the abdomen, tubed, and slid over the index and little fingers. The dorsum of the hand was covered with a free graft. The end-result is shown (Fig. 8). After replacement of the pulp with a free graft the thumb was functionally normal. This patient can now grip and pick up small objects.

Reconstruction of the Thumb

The position the thumb holds in the function of the hand is unique. Not only is it the key opposition element, but its weight-bearing surface is requisite in all composite movements. Loss of any part of the thumb constitutes a serious disability, and the methods used for its repair and reconstruction are dependent upon the amount of tissue loss. The provision of skin cover for the terminal phalanx has been discussed, and loss of less than half of this phalanx does not justify more radical procedures. Loss of

FIG. 4

FIG. 5

FIG. 6

FIG. 7

the terminal phalanx can, to some extent, be compensated for by apparent lengthening, a procedure known as phalangization, whereby the thumb web is deepened and the defect so created lined by a free graft. When the terminal loss of the thumb is of such an extent that it no longer reaches the level of the second cleft, then additional length should be provided to attain this level.

There are three commonly used methods for adding length to the thumb, each dependent on the degree of tissue loss :

FIG. 8

FIG. 9

(1) the chapeau flap of Gillies, (2) the tube pedicle and bone graft, and (3) pollicization. The preservation of normal skin with normal sensation in the thumb adds greatly to its functional place in the hand, and for this reason the chapeau flap is the method of choice where the additional length required does not exceed $\frac{1}{2}$ in. (2 cm.). It is essential, however, that minimal terminal scar should be present; otherwise necrosis will supervene and lead to loss of the bone graft. The following is an example of the chapeau flap. This patient, operated upon by Mr. Rainsford Mowlem, lost the terminal phalanx of his thumb while working a circular saw. A curved incision was made around the base of the thumb and the skin dissected off, superficial to the venous plexus, until it could be slid over the end of the bone, attached only to the first cleft. An autogenous bone graft of the desired length was fixed to the end of the bone and the skin replaced. A skin defect created at the base of the thumb was made good by a free graft. Fig. 9 shows the hand before and after operation.

In cases where the loss in length exceeds that of the terminal phalanx, a simple opposition post constructed by a tube pedicle and bone graft adds considerably to the function of the hand. The patient should be warned that for the first six months after reconstruction the skin is anaesthetic and should be protected against excessive heat and cold. Thereafter, a degree of sensation is present which is sufficient to protect the area from injury. Fig. 10 shows the hand of a patient who lost his thumb and three fingers. A tube pedicle from the right side of the abdomen was grafted on to the hand. After the pedicle had been detached

from the abdomen it was opened and an iliac bone graft inserted into the stump of his metacarpal. With his little finger and reconstructed thumb he was able to grip and resume his pre-accident occupation of gardening. The end-result is shown.

Pollicization

Where the thumb has been amputated down to near the base of the metacarpal, pollicization of the index finger must be given serious consideration. The hand with four fingers but without a thumb is a poor functional unit compared with a thumb and three fingers. This procedure has been fully dealt with by Cuthbert (1949). In those cases where the trauma to the hand has at the same time damaged the index finger, pollicization is the method of choice.

An example of this is the case of a boy who caught his hand in a lathe. The thumb had been amputated through the base of the metacarpal. The proximal phalanx of the index was left; but the skin was beyond repair. An immediate abdominal flap was utilized to repair the defect in the first instance (see Fig. 11). Later the index was pollicized. A flap from the dorsum of the hand was elevated and the interosseous muscle between the index and middle metacarpals was split. The second metacarpal was sectioned near its base. An incision was then made in the palm and the artery to the middle finger isolated and divided; the digital nerve was then split proximally. The deep transverse ligament and the adductor pollicis were divided; the index was then rendered freely mobile. The second metacarpal was wired to the base of the first. The extensor tendon to the index was sutured to the extensor pollicis, and the dorsal flap was wrapped around the pollicized digit so as to give good local skin cover on the flexor aspect. The defect on the dorsum of the hand was covered by a free graft. Fig. 12 shows the end-result.

FIG. 10

At a later date the pollicized digit should be provided with an opponens tendon transplant, as there is a marked tendency for the digit to take up a position of adduction deformity. This deformity has been corrected and both opposition and abduction have been much improved in the case described. This addition to the method of pollicization has proved to be an advance on the earlier technique used.

Major Hand Reconstruction

In injuries of the hand where all the digits have been lost, the objective is the provision of a forceps type of hand by lengthening one or two metacarpals with bone

FIG. 11

FIG. 12

grafts covered by flaps or tubes of skin, and the reduction of the intervening metacarpal remnants. These two rays can be motivated by tendon transplantation to provide a simple means of opening and closing the forceps to enable the patient to grip. The provision of a mobile wrist-joint is of first importance in the functional end-result of this type of hand, and every effort should be made to achieve this by early active movements. It is interesting to observe how children with congenital absence of the fingers and a normal wrist-joint can adapt the palm and the dorsum of the hand to a surprising degree of usefulness.

Multiple Injuries

Damage to the hand, particularly in industrial accidents, may be associated with injuries to bone and soft tissues proximal to the wrist, whose immediate treatment and functional recovery are problems inseparable from those of the hand. Two cases are presented to illustrate these points.

One patient caught his arm in a cement mixer. In addition to a severe hand injury he had, in the same arm, a fracture of the lower end of the radius and a dislocation of the elbow. The dislocation was reduced, the fracture of the forearm plated, one finger amputated, and the other repaired. He recovered full function and returned to his pre-accident occupation.

In this type of case it is not only desirable to effect a one-stage repair, it is equally desirable to initiate composite movements of the entire limb in its rehabilitation.

The other patient caught his hand in an automatic die-casting machine with spikes. There was skin loss on the dorsum and palmar aspects of the hand associated with comminuted fracture of the lower end of the radius. There was a large area of skin loss on the dorsum of the wrist, exposing the fracture. The hand was repaired by free grafting, the radius was plated, and an abdominal flap was elevated and inset into the forearm to cover the plated bone. All areas healed without complication.

Summary and Conclusions

An attempt has here been made to illustrate accepted methods of using skin cover to repair injuries of the hand, the aim being to limit the loss of tissues that may affect the functional end-result. Primary skin cover reduces the incidence of infection and preserves deeper structures which would not normally remain viable if exposed. At the same time as the skin cover is provided, the underlying structures are rearranged so as to place them in the optimal position for the reconstructive phase. The stages of hand repair present a composite picture, each one being related to and dependent upon the other. Each stage must be consolidated by maximal functional recovery before proceeding to the next.

Transported skin must be toughened up and rendered freely mobile, tendons and nerves allowed to unite and function, joints activated, and the hand integrated into the synergic mechanism of the whole upper limb.

Throughout treatment, rehabilitation by those experienced in the care of damaged hands can do much to establish new cerebral patterns to compensate for loss or limitation of movement. Undesirable defence mechanisms and trick movements can be corrected and avoided by careful re-education as the stages of reconstruction proceed. In the end the patient should be left, not with a useless monument to the technical skill of the surgeon, but with a functional unit patterned on a conception of his primary requirements—earning a living and the performance of his usual daily tasks.

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The British Pharmaceutical Conference, which has just concluded its 93rd meeting in Dublin, has accepted an invitation from the Bristol and district branch of the Pharmaceutical Society of Great Britain to meet in Bristol from September 2 to 6 next year.