THE PRESENT STATUS OF REPLANTATION OF DIGITS*

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INTRODUCTION

The introduction and adoption of using operating microscope and micro-instruments in surgery had made a giant step in opening up a wide frontier in surgical fields. One of its greatest impact is to make reattachment of digits and limbs which require micro-anastomosis of vessels with diameter ranging from 0.5 millimeter to three millimeters feasible.

The developmental milestones of this medical advancement which is really a technical advancement has been a relatively short one — less than two decades. To talk about the present status of advancement of this speciality, one must look back and pay tribute to the original pioneers in this field.

MILESTONES IN REPLANTATION SURGERY

One of the earliest pioneer in the field of micro surgery is Julius Jacobson who developed the essential micro-instruments and technique in 1960 to enable successful suture of vessels of external diameter less than one millimeter. Although many microsurgeons had developed other techniques (e.g. glue and stapling) to bridge the divided vessels, these methods are more tedious and less reliable as compared to the original Jacobson's technique of manually suturing the divided vessels.

The first reported successful replantation of the limb (forearm) was from China, the Shanghai Sixth Municipal Hospital, by a team of surgeons headed by C.W. Ch'en, Y.C. Ch'ien and Y.S. Pao. Surgery was carried out on 2nd January, 1963 and was reported in the Chinese Medical Journal in the same year. The real impact of the news was received with great enthusiasm in the medical world only when J.S. Horn, a British surgeon in Peking reported the case in the Lancet in May 1964. Since then, China had been the Mecca where every replantation surgeon must pay homage. In the same year (1964), Ronald Malt and C.F. McKhann reported their successful replantation of completely amputated arm in the J.A.M.A. These two isolated reports had been outside the "Microvascular" range.

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*Paper presented at the 5th Combined Singapore-Malaysia Orthopaedic Meeting, November 1977.

From 1960 to 1966, Harry Buncke and his associates worked on experimental animals followed by the clinical application of microvascular sutures of small vessels in human. Buncke and his associates successfully transplanted a big toe to the stump of an amputated thumb in 1966. Similarly, S. Tamai (1966 Cobbett) from Japan reported the first successful replantation of a totally amputated thumb by doing both arterial and venous repair although it was known later that partial success in digital replantation had been achieved in 1964 in China.

CLINICAL APPLICATIONS OF MICROVASCULAR SURGERY

The present replantation surgery, as I have mentioned earlier is really a technical advancement. The enormous medical knowledge which we have acquired through unfailing research of these people have widened the clinical applications of microvascular surgery to other fields in different specialities for other purposes like free flap transfer (Daniel, Taylor, O'Brien, Harii and Omori, 1973), free vascularised bone graft transfer (Taylor, 1975), free vascularised nerve graft transfer (Taylor, 1976) and free vascularised muscle nerve transfer (Ikuta, 1976).

With the availability of micro-instruments and operating microscope, there is the rapid mushrooming of replantation centre in every major city in the world. While every replantation surgeon may have slight variations in their technique and each may have their own special preference of using special instruments or suture materials, the general principles and the actual techniques are nearly always the same.

THE TECHNIQUE AND SEQUENCE OF REPAIRS IN REPLANTATION OF DIGITS

In the University Department of Orthopaedic Surgery at Singapore General Hospital, we have adopted the following technique:-

1. **Skin debridement and preliminary identification of neuro-vascular bundles** (using loop magnification or operating microscope).

2. **Bone fixation:** We advise minimal bone shortening if possible and we use one of the following methods for bone fixation:-

   (a) K-wire (axial or criss-cross fixation)
   (b) Longitudinal wire compression
   (c) Screw

This is one of the most important and difficult step in the whole procedure especially if no proper instruments are available.

3. **Extensor tendon repair:** We use 4/0 dexon mattress suture for the extensor tendon repair. We find that the repair of extensor tendons over the digit is most unsatisfactory as accurate restoration of anatomical arrangement of the central and lateral slips are often not feasible due to much contusion and loss of the tendons.

4. **Flexor tendon repair** is carried if indicated by using Bunnell's suture of 4/0 wire and circumferential epitendinous suture using 6/0 ethilon.

5. **Digital nerve repair:** We use 8/0 ethilon. About four to six sutures are inserted. The repair is often very unsatisfactory under the operating microscope as nerve bundles are often seen to buckle out from nerve sheath.

6. **Digital artery anastomosis.**

7. **Dorsal vein anastomosis:** We prefer to anastomose the dorsal vein after completion of digital artery anastomosis. By doing this, the distal vein will be distended for easy identification of suitable vein distally for anastomosis. Its main disadvantage is to produce a bloody field and excessive blood loss (which often amount from one to 1.5 litre of blood loss).

8. **Fasciotomy** in those cases with
   (a) prolonged ischaemia — e.g. delayed transport or in multiple amputations;
   (b) inadequate venous return from poor venous anastomosis or venous thrombosis.

MICROVASCULAR SUTURE OF DIGITAL VESSELS

In microvascular suture of digital arteries and veins we use 10/0 ethilon suture material which we find to be adequate in vessels of diameter ranging between 0.8 to one millimeter.

After identification of both proximal and distal ends of the vessels, Ikuta's vascular clamps are applied to both ends of the vessels. Contused vessel ends are resected until normal healthy vessel walls are seen. We do only minimal stripping of adventitia to prevent it from being caught within the lumen.

Before the placement of suture, the lumen of vessels are inspected under high magnification (40X) to make sure that it is clean of all the debris (e.g. clot and fat, etc). Sutures are inserted at a high magnification (40X) to ensure correct biting of vessel edges and spacing of sutures. The magnification is then zoomed down for tightening of knots. Two stay sutures are introduced at 120° angle initially to allow the posterior wall of the vessels to fall away. After completion of anterior vessels wall anastomosis, the

vessel is then turned for the posterior wall anastomosis. During the procedure, the vessel wall is constantly moistened with heparin solution. On completion of the first digital artery anastomosis, 500 millilitres of dextran 10% is commenced before releasing the vascular clamps. In an average digital artery of diameter ranging from 0.8 to 1.2 millimeters, five to seven sutures are adequate. In case of digital vein with diameter ranging from one to two millimeters, eight to ten sutures are adequate.

ANTICOAGULANT THERAPY

We believe that the accurate placing of sutures, minimal handling of vessel walls and anastomose only the healthy vessels are the most important in preventing thrombosis. We use dextran 0.5 to one litre per twenty four hours for one week and aspirin one to two grams per twenty four hours for six weeks which are the same as others working in this field. We use local heparin solution for irrigation during the procedure and do not use systemic heparin routinely (except on two occasions only) after surgery. Most people differ in this aspect. O'Brien (1977) insisted that systemic heparin is very important and he used it routinely. Local antispasmotic agents like paparin or local anaesthesia and $MgSO_4$ have not been proved to be really effective. Besides there is the uncertainty that it may produce local damage to the initima.

In problem cases when salvage procedure is required all the way, e.g. in the thumb with avulsion injury with loss of vessels and nerves, the use of primary neurovascular bundle transfer, vein graft or dorsal digital vein transfer are very useful in salvaging the amputated part which appeared to be very hopeless initially.

Case example

The following case illustrates the problem well. (Fig 1a). This patient aged twenty sustained a degloving type of injury when his hand was caught in a drilling machine and has

(1) complete amputation of the right thumb at the base of metacarpal. Flexor pollicis longus was avulsed four inches high up. All the thenar muscles were completely avulsed and crushed, digital neurovascular bundles were contused and avulsed high up both on ulnar and radial sides. It was not possible to do a direct end to end digital artery anastomosis.

(2) Right index finger showed amputation at the level of the base of the proximal phalanx with no skin cover over the second metacarpal head.

After thorough consideration, it was decided that the right index finger should be sacrificed in order to facilitate the rehabilitation and at the same time, neurovascular bundle of the index finger could be mobilised and transferred to restore the circulation to the thumb. On completion of neurovascular transfer and anastomosis, there was good perfusion distally. Two dorsal veins were anastomosed but unfortunately the venous anastomosis were exposed without soft tissue and skin cover. Skin graft was taken from the amputated index finger to cover the skin defect over the first web space on he dorsum of the metacarpophalangeal joint of the thumb. The skin graft was directly applied over the anastomotic site of two veins. Flavin wool was used to compress the skin graft.

The thumb however became slightly cynosed ten hours after the first surgery. This indicated venous engorgement with inadequate venous return. The thumb was re-explored eighteen hours after the first

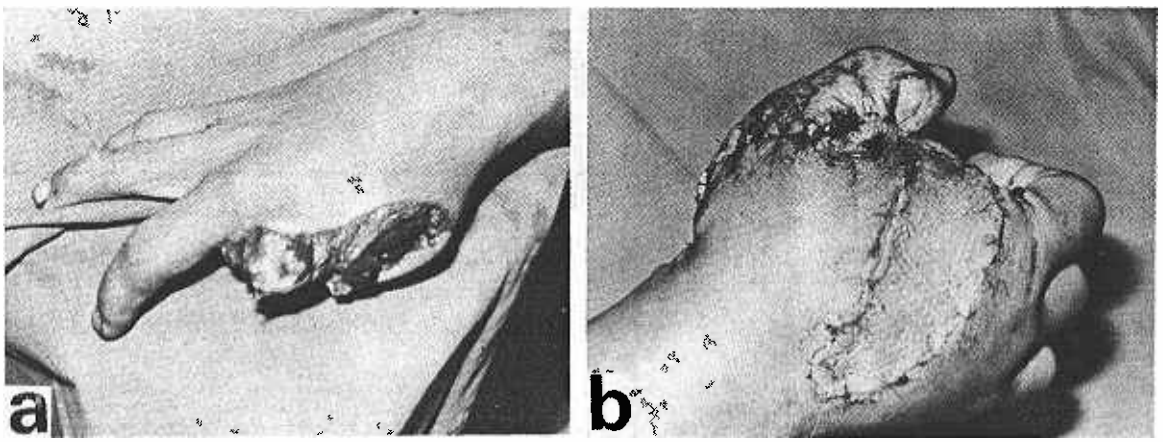

Fig. 1a shows degloving injury with loss of the right thumb at the base of metacarpal and index finger at the metacarpophalangeal joint level. The index finger was sacrificed to facilitate neurovascular bundle transfer.

Fig. 1b After second exploration, dorsal digital vein was transferred. Two rotational flaps were raised from the palmar and dorsal aspects of the 3rd finger to cover the anastomotic vein.

surgery. After removal of all the dressings and skin graft, the anastomotic dorsal veins were found to be extensively thrombosed. Both the thrombosed anastomotic veins were resected and thrombectomy was carried out by milking the thrombus gently with forceps and injection of heparin into the lumen. There was considerable difficulty in finding the proximal veins and one dorsal vein transfer from the dorsum of the hand had to be carried out. Two venous anastomoses were carried out and there appeared to have good venous return. Two rotational flaps were raised from the palmar and dorsal aspects of the third finger to cover the anastomotic vein. (Fig 1b) The resulting skin defect was covered with split skin graft. The colour of the thumb was good with no tension over the pulp.

Twenty four hours after the second surgery, the thumb looked cynosed again indicating re-thrombosis and re-exploration was carried out. There was extensive thrombosis with mural thrombus within all the veins found, extending as distally as interphalangeal joint. The vein was found to be stiff and thickened indicating phlebitis had set in. After careful thrombectomy as much as we could achieved, a vein graft was used to bridge the gap to restore venous return. However, the venous return was still inadequate and we had to rely on extended fasciotomy to allow bleeding externally. The patient was commenced on systemic heparin therapy. Unfortunately his haemoglobin dropped to six milligrams percent and he developed complication from heparin therapy and all anticoagulants had to be stopped. Subsequently the thumb became cynosed from venous re-thrombosis and dry gangrene set in from progressive thrombosis. He eventually lost his thumb three weeks after the initial injury.

Altogether this patient spent almost twenty one hours under general anaesthesia during his first seventy two hours after admission in hospital.

We were aggressive and all out to save this thumb because we knew that the price we paid if the operation was unsuccessful was very expensive. At the same time one had to remember that there must be a limit of one's ability and not to lose the patient from the complication of therapy.

SURVIVAL RATE OF REATTACHED DIGIT

With the technique which was just described, most replantation centre produceddifferent figure for survival results varying from 45% to 90% (Weiland, 1977; Biemer, 1978).

The Sixth People's Hospital had survival rate of 45% and this included their early results where magnification with operating microscope was not available. Our results with a small series of thirty one digits where reattachments were attempted had a relatively high survival rate of 85% (Pho etal, 1977).

While the initial survival success depend only on microvascular anastomosis of healthy digital vessels and good skin cover, the ultimate success will depend on functional result of the reattached digit after total reconstruction.

FURTHER MANAGEMENTS

Most patients will therefore require further surgery consisting of prolonged and multiple hospital admissions for :-

1. **Multiple operations** e.g. re-exploration
   shortening of K-wire
   removal of K-wire
   skin graft
   silastic rodding
   tendon graft or transfer
   amputation
2. **Angiography** before secondary tendon reconstruction.
3. **Rehabilitation.**

Case example

This is best illustrated by this young girl aged sixteen who had amputation of the left index finger in April 1977 at the proximal phalanx level. (Fig 2a). Reattachment of the index finger was carried with two digital arteries, one dorsal vein and extensor tendon reconstruction. She has first stage silastic rodding done. The wound broke down and the distal end of the silastic rod protruded out. (Fig 2b) At this stage, she was fed up with the whole thing and was in tear and sick of exercises at the Physiotherapy Department. The rational approach was to remove the silastic rod and allow wound healing first, followed with reinsertion of silastic rod at a later date when the wound has healed then followed with tendon graft. This meant three further operations which she was not willing to go through.

To re-introduce smaller silastic rod at this stage would not work as the rod would continue to produce foreign body reaction and a pulley reconstruction would be required at the tip level. The area was not grossly infected and perhaps insertion of free tendon graft was possible — except one is putting an avascular structure within an inflammed sheath, adhesion or breakdown is likely.

After consideration of all the factors, tendon transfer was thought to be the most justified here as it confered one operation and a viable structure could

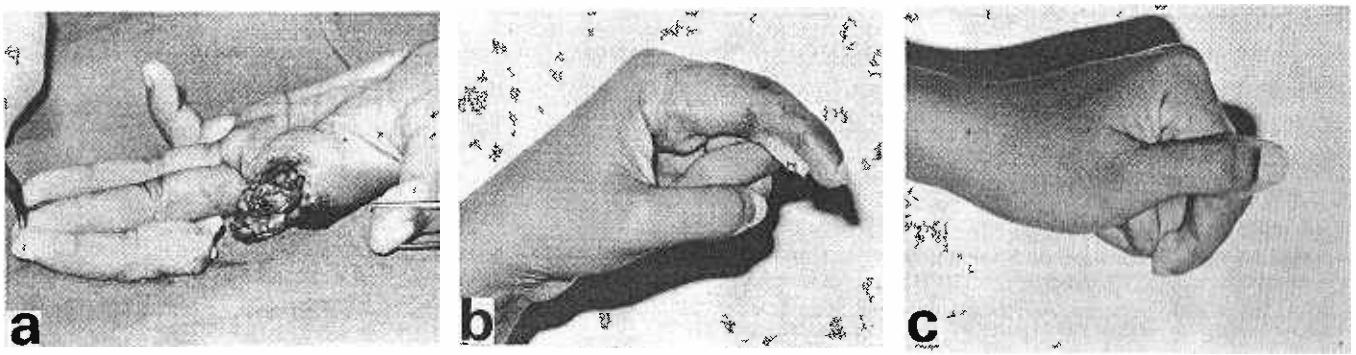

Fig. 2a Traumatic amputation of the left index finger at the proximal phalanx level.

Fig. 2b Six weeks after insertion of silastic rod. The wound broke down showing tip of silastic rod protruding out.

Fig. 2c After tendon transfer and pulley reconstruction showing range of active flexion of reattached digit which the patient found to be useful.

be placed within the sheath. The index finger was then syringed with cloxacillin solution and sublimis tendon from the middle finger (after sacrificing of one slip) was anastomosed to the base of the distal phalanx of the index finger as one stage procedure. A sling was reconstructed over the proximal phalanx to prevent bowstring effect and facilitate skin closure. The healing was uneventful. The patient now has good active flexion at metacarpophalangeal joints and find the reattached index finger useful. (Fig 2C)

FUNCTIONAL RESULTS

What are the functional results after all these procedures?

We can classify the functional results into three groups:

1. Near normal digit.
2. Useful digit.
3. Chronic failure with stiff painful digit.

It is difficult to get near normal digit in group one except in those cases when it was a clean cut wound of the thumb and a total reconstruction of all the structures were possible as a primary pocedure. (Fig 3) However, in most cases one can give the patient a useful digit. In the thumb, 90% success can be guaranteed. But let me emphasize that there is no such thing as "all or none" law, i.e. if the finger survives then it means success. We probably can state that if we indiscriminately reattach all the fingers, there is a good chance that 50% of the patients will come back with stiff and painful digit requesting an amputation of the reattached digit — a most unpleasant yet justified request on the part of the patient.

CRITERIA AND INDICATION OF REPLANTATION OF DIGIT

To avoid shattering our ego of early euphoria from initial survival success, it is very important that we must have criteria and clear indications before embarking on replantation of the digit. It is the selection that ultimately may determine whether the procedure is a triumph of the technique. Each case must be considered on its own merits. Apart from the availability of expertise service and duration of ischaemic time, there are other factors which we must look into:-

(1) Age of the patient

We probably should attempt to replant all cases in

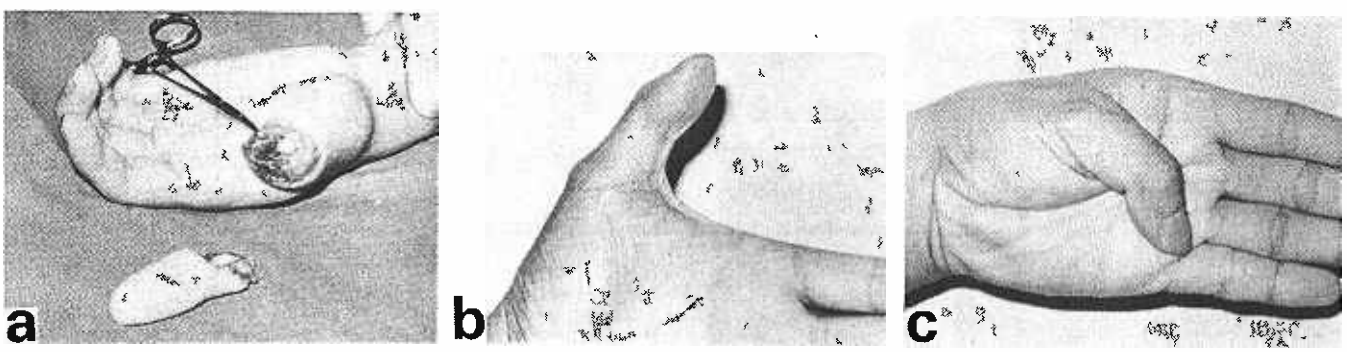

Fig. 3 Complete amputation of the left thumb at the metacarpohalangeal joint level. Total reconstruction of bone, ligaments, tendons, nerves and vessels were done primarily. Patient was discharged from the hospital within two weeks after surgery. Near normal thumb was achieved six months after reattachment.

children if feasible in view of unknown future potential of the their occupation. Besides, the younger the patient, the more likely of regeneration of peripheral nerves and ease of rehabilitation, the functional result is often good. In elderly, one should be more cautions and selective. For those who seemed very well motivated, replantation may be elected.

(2) Mentally stable patient

Good results will undoubtedly be obtained from those patients who are psychologically sound and co-operative with postoperative rehabilitation. However, it is often difficult to evaluate a person's mental state in the stress of moment. One must beware that while the reattached digit will survive, the patient may be crippled significantly by not rehabilitating the part and creating more disability for secondary amputation in order to get a bigger slice of workman's compensation.

(3) Profession

In skilful worker who needs his pulp for pinching, reattachment may be indicated. Length is important in any digit.

(4) Level of amputation

The distal the amputation, the more difficult it is indentifying the vessels for anastomosis. However, the ultimate result is better as the stiffness of the distal joint does not constitute a great disability and the potential of nerve regeneration is good. We can also get away without doing venous repair - venous return being relied solely on external bleeding through fasciotomy wound.

(5) Type of Injury

Avulsion or degloving type of injury often produced extensive damage to the long segment of vessels which will require major resection of damaged vessels. Technically salvaging of the digit is very difficult. It often involves massive resection of bone, vein graft and neurovascular transfer.

The other indications depend on the digit involved.

Thumb:

Because the loss of the thumb is equivalent to the loss greater than 50% of the function of the hand, every attempt should always be made to replace an amputated thumb.

Multiple Finger Amputations :

We must consider the possibility of salvaging the part of a finger that can be used as a "bank" for future reconstruction. Therefore we should probably replant whatever is possible. In most cases however, due to the length of operative time, we prefer to do primary reconstruction of the hand with the aim of getting maximal functional results.

The Single Finger amputation :

We probably should be very selective. Remembering that by replanting the patient's finger, the patient will have at least three months off work. This may be more crippling to him and his family than the loss of only one single digit. Most people would probably recommend replantation surgery in this situation as Cobbett had advocated:-

(1) Ring finger of unmarried girl.
(2) Index finger in highly skilled technician.
(3) Any digit for cosmetic reasons in model, doctor, pianist and **patient's own wish.**

I am uncertain of medico-legal responsibility on the part of the surgeon for refusing to reattach the finger if the patient wants it done.

CONCLUSION

I have outlined the present status of the technique, the results and indications of replantation of digits.

However, it is worth remembering that in those cases of reattachment where total reconstruction of all structures can be done primarily and the patients are discharged home within two weeks of admission from the hospital, will almost have near normal digit (Fig 3). They do not pose any problem and many people regard the operation as no different from a simple "toilet and suture" as one of my colleagues have said. In those cases with chronic failure with painful stiff finger which require prolonged and multiple hospital admissions will often be reviewed by many people. I am sure that in this room, there are many of us who still cast a doubt if reattachment is really worthwhile? I have shown two cases where we have used all our resources of medical knowledge and technical know how to save the digits when complications arise.

Perhaps, I may conclude this talk by asking all of us who are involved in this work by looking at the **perspective of replantation of digit** as R.A.Malt had nicely stated:-

Is the replantation a purely technical exercise on the part of the surgeon that may actually be a liability to the patient **OR** can the replantation offer functional end results that no other form of therapy can?

In my mind, there is no doubt that while there is no prosthesis that can substitute human hand, provided we stick to the criteria and indication which had just been outlined before we embark on surgical replantation, the reattached digit would offer much superior function than prosthesis and worth all the effort!

ADDENDUM

In Singapore, replantation of the forearm was successfully carried out on 12-4-1975 (LEONG 77) and successful replantation of the completely amputated thumb was achieved on 21.1.77 (Pho et al, 1977).

ACKNOWLEDGEMENTS

I wish to thank Mr S.S. Moorthy and Mr S.H. Tow for the photographs and Miss Janet Soh for her secretarial help.

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