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THE OPERATING MICROSCOPE: A NECESSITY OR A LUXURY?*

By D. Angus McGrouther, M.Sc., (Bioengineering) F.R.C.S., F.R.C.S. (Glasgow).
Shotley Bridge General Hospital, Consett, County Durham, England.

The sport of clinical micro-reconstructive surgery has provided much excitement in the plastic surgical literature for players and spectators alike. Originally a young man's pursuit, microsurgery has more recently developed a wider appeal, promoted no doubt by dramatic reports of the state of play; "Successful replantation of a completely cut-off thumb" (Komatsu and Tamai, 1968); "Free great toe transfer" (Cobbett, 1969); "The smallest digital replant yet?" (Kubo et al., 1976); "The youngest free groin flap yet?" (Ohmori et al., 1977).

The time cycle has been rapid particularly in this country. Only four years have passed since a single case of multiple digital replantation was reported by Bowen and Poole, (1975).

Papers have given way to textbooks thus establishing permanently the milestones of reconstructive possibilities. Throughout there has been much controversy about who did what first. The record-breaking aspect of the sport has been much stressed, but there is now a need for an appraisal of the role of microsurgical techniques in routine clinical practice to establish whether the operating microscope is a necessity or a luxury.

To solve this dilemma we must ask certain basic questions. What does the operating microscope enable us to do that we cannot do without it? If we can do it, are the results better than those achieved by alternative macroscopic means? Do the results justify the investment in man hours and theatre facilities? In this essay it is proposed to examine certain areas of microsurgical endeavour: replantation, free tissue transfer, nerve repairs and other applications in reconstructive surgery.

General Observations on Replantation

Replantation of parts has been achieved using conventional vascular surgical techniques where the vessels are 2 mms in diameter, but with smaller vessels it is generally agreed that magnification is required for success.

Replantation by vessel anastomosis as far distally as the proximal interphalangeal joint was being performed in Shanghai in the mid 1960's using loupe ($\times 3$) magnifying spectacles. (Replantation Surgery in China, 1973). At higher magnifications extra illumination is beneficial and in practice in the

*This paper was the prize-winning entry in the Kay-Kilner Essay Competition for 1979, awarded by the Council of the British Association of Plastic Surgeons. Mr McGrouther is Consultant Plastic Surgeon to the Plastic Surgery Unit at Shotley Bridge General Hospital.

upper limbs a microscope is generally used for vessels distal to the wrist. Most human microsurgery is performed with magnification ranging from ×6 to ×10. A trained microsurgeon will in any case find operating on somewhat larger vessels easier with the microscope than without. For replantation the microscope is therefore a relative necessity for the actual performance of the procedure, but how essential is replantation? How good are the results?

Certainly, scalp replantation *must* be attempted, no other means being possible for reconstruction of appreciable areas of scalp, where the only important function that must be achieved is the growth of hair (McGrouther *et al.*, 1980).

In limb replantation overall success, measured as viablility, of the order of 85% has been achieved in a large series by Biemer *et al.*, (1978).

In the upper limb most microvascular surgeons would advise replacement of thumbs, whole hands and multiple fingers. The replantation of single fingers is more controversial as it is argued that a stiff and insensitive digit may result. It must be borne in mind, however, that the damage in a replanted finger is merely a combination of a compound fracture together with injuries of the flexor tendon (often in no-man's land), extensor apparatus and nerves and vessels, all of which individually in the past may have been treated by amputation, but all of which, treated well, can be compatible with good function. It seems reasonable that if the best vascular repair can be combined with the best tendon repair, osteosynthesis and nerve repair much better functional results should be possible. Our bone and tendon surgery must be improved and perhaps we should use earlier passive tendon mobilisation in these cases, bearing in mind the difficulties in actively mobilising an anaesthetic part. Problems of stiffness, anaesthesia and cold intolerance may well all be avoidable by better primary management.

Rules such as "Don't do single finger replants" can only be made after scientific retrospective analysis of a large number of such replants using the best possible repair of individual structures. Such figures do not as yet exist.

Better than "Rules of Thumb" the patient should make the choice for or against replantation after informed advice on the likelihood of functional recovery, time off work, taking into account his own social, economic and aesthetic preferences.

"Rules of Thumb" may also turn away the badly assessed case from elsewhere, perhaps not even completely severed, and a plea must be made for the "replanter" to assess the potential "replantee" personally. In considering operation every case must be assesssed on its merits. It is too early to draw up absolute rules. It has been categorically stated for example, in the past that if the vessels have been avulsed replantation should not be attempted, but Biemer has now shown that success can be achieved by the use of microvenous grafts.

Functionally and aesthetically nothing is as good as a whole hand and it is remarkable how much attention is focused by the media on people in public life who may have only lost a distal phalanx.

In assessing results replant function must be related, not just to the normal hand, but to the hand without the part. It is clear that although many replants are necessary in the sense of being worthwhile, some attempts could perhaps be regarded as a luxury but too little reliable information is yet available on the late functional results.

Theatre Facilities: Organisation and Methods

Traditional theatre organisation and thinking tends to regard a surgical emergency as a swift and short intervention, but long reconstructive procedures demand a complete departure from this routine.

The anaesthetic and nursing staff will quickly become bored with a long replant operation and can easily unsettle even the most placid surgeon. This problem of boredom has been tackled in the Klinikum Rechts der Isar in Munich where upper limb replantation is generally done with axillary block anaesthesia administered by the surgeon. Only one nurse is present to assist. A separate theatre is designated for replant surgery and recently a patient has been operated upon in his own bed to which an arm table was attached. Attention to these points could avoid theatre overmanning and the blocking of other emergency theatre facilities. Another way to reduce boredom is to attach a video camera and monitor to the microscope to allow others present to see what is happening. The cost of this equipment is now a fraction of the cost of the microscope itself.

"Who Should be Doing Replantation?"

Compared with published large series from abroad (Replantation Surgery in China 1973; Biemer, 1978) the total experience in Great Britain is small, an observation confirmed at meetings of the Microsurgical Travelling Club. The smaller number of suitable cases may be due to better safety standards in industry, a generally low level of industrial activity and a small timber industry which seems particularly prone to produce such accidents. Failure to refer suitable cases is often due to ignorance of the possibilities of surgery and dissemination of accurate information on the successful cases should help correct this fault.

In view of the small number of cases referred would it be better to centralise replantation in this country to a single or small number of centres? In West Germany a well-designed system of helicopter transport for road accident victims has allowed the rapid transportation over long distances of patients suitable for replant surgery. If it were feasible to get all the cases to one centre within twelve hours, the potential advantages for the patient and the surgeon would be immense. No centre in this country can at present offer to trainees the volume of experience or the technical facilities available elsewhere.

The training of a microsurgeon must begin in the animal laboratory, followed by exposure to replantation problems in man before embarking upon the possibilities of free tissue transfer. Although the occasional replanter may achieve good results (the author has successfully replanted a hand in a District General Hospital using a portable microscope carried in the boot of a car) this is a poor compromise and certainly no trainee will acquire sufficient sound experience from such attempts. Perhaps one Plastic Surgery Unit or a few in combination should develop a National Replantation Service, not to exclude those who are trained and interested in performing the occasional replant, but to provide sufficient work to train future generations of microsurgeons.

Free Tissue Transfer

The possibilities of free tissue transfer opened up by microsurgical techniques include skin with subcutaneous fat, bone, or combinations of these tissues, fat, omentum, gut, muscle as a space filler, muscle as a functional unit. The list is still incomplete. Free tissue transfer is in its infancy: new and even better donor sites are constantly being reported in our journals.

Let us consider primarily the use of free flap transfer in the provision of skin cover. Initial enthusiasm resulted in attempted free flap cover of many sites where simple conventional means would have been adequate. For a time some surgeons were seeking every and any indication for using a microvascular free flap transfer. Rarely in surgery have we seen so much written in justification of a new operation: or were these papers expressing an underlying feeling of guilt that simpler well-established techniques might have been more suitable? However only by doing an operation can its limitations be defined and it has always been a sound plastic surgical principle to have another method in reserve, "just in case"! The initial surge of case reports has been stemmed by two factors: the time taken to complete the repair and the success rate.

The time factor is relatively insignificant if success can be assured. It is therefore important to examine the causes of failure for if success could be assured then the indications would widen enormously.

The advantage of skin cover by free flap transfer must be compared with the success of conventional methods. Morris and Buchan, (1978) quoted a 94% success rate with cross leg flaps providing a clinical yardstick that must be used in assessing the benefits adduced to justify free flap skin cover.

Potential advantages are a one-stage operation, a wider selection of donor sites to provide the most suitable skin and the least disfigurement, but these must be weighed against the price and problems of possible failure.

The new development of muscle flaps, musculocutaneous flaps and even osteo-musculocutaneous flaps have dramatically curtailed the indications for free flap skin cover. The early "epidemic" of free skin transfer to the pretibial region has been checked by the introduction of gastronemius and soleus muscle or musculocutaneous flaps. Only very extensive local muscle damage in the leg can now make free flap transfer preferable but in these cases dense scar may make access to the vessels difficult, if not impossible.

The two sites where free flap transfers are at present most suitable are the top of the head and the lower extremity distal to the calf muscle bellies: but even these sites are no longer safe from more recently developed techniques.

Although the hand can be reached by pedicled skin flaps the potential benefits of elevating the hand post-operatively and allowing free shoulder and elbow movements have strengthened the case for free flap skin cover. But in general the early enthusiasm has waned in favour of safer and simpler methods.

It is known that nearly 100% patency can be achieved with anastomoses of 1 mm vessels in laboratory animals (O'Brien, 1977). Why, therefore, should an anastomosis ever fail in man? The answer probably lies not so much with the vessel anastomosis itself but rather with anatomical difficulties in the donor and recipient sites.

Donor site problems are due to the difficult planar anatomy of the flaps.

In the groin flap, for example, the vessels lie in fat and are therefore not easily seen. In the dorsalis pedis flap the axial vessel must be followed into the depths of the intermetatarsal space to allow elevation of the vessels in the flap. By contrast the latissimus dorsi myocutaneous flap has a large vessel which is easily found by blunt finger dissection.

Recipient vessel trauma or extensive scarring makes vessel dissection difficult. The design of flaps with larger vessels and longer vessel leashes such as the latissimus dorsi flap allows easy anastomosis at a distance. The vessel leash must not only be long enough, but must lie at the correct position for anastomosis.

Disease in the blood vessels in man is not an important cause of a failed anastomosis. "Spasm" however is variable in its incidence and severity. End-to-side anastomosis has recently gained popularity following the observation that an incompletely divided vessel will continue to bleed as retraction, due to spasm, is prevented. Apart from perhaps giving a better flow, the main line flow is preserved which, in the lower limb, may be advantageous in later years.

When we consider the question of man hours and theatre usage complicated statistical equations based on "bed-time" saved by free tissue transfers at the expense of "theatre-time" used give only part of the picture. In our Health Service bed occupancy figures are often used as a yardstick to justify expansion of facilities. In this respect microsurgery is counter productive by saving "bed-time" for the microsurgery case and blocking "theatre-time" which could be otherwise used to operate upon "longer-stay" patients. Although many free tissue transfers have lasted "all-day", the recent trend to use more easily raised flaps with longer vessels has transformed the time scale so that complex procedures can be regularly completed within four hours.

Nerve Repair

Whatever may be said about microsurgery in nerve repair the correct training for a microsurgeon must be through microvascular repair. It is too easy for the inexperienced to "disappear down a microscope", doing something to the nerve and generally bringing the microscope into disrepute. A patent flowing vascular anastomosis in a laboratory animal gives visible proof of the basic competence that must be attained before embarking upon clinical microsurgical work.

In managing injuries of the peripheral nerves, an appreciation of the pathology of injury is important. Axonotmesis is a recognised degree of injury after a crush in which the axons are interrupted but the fibrous tissue framework of the nerve is preserved. Distal Wallerian degeneration occurs but near-normal recovery is possible. After nerve division, Wallerian degeneration also occurs but the recovery is never as complete due to mis-matching and loss of axons growing out into the tissue at the suture site.

Logically the aim of surgery in a nerve transection must be to create as closely as possible the state of axonotmesis in which there is perfect matching of the fibrous tissues. The crucial factors therefore are perfect matching and apposition: the perennial argument about epineural versus perineural suture is a red herring.

The place of microsurgery in nerve repair has been recently summarised by Sir Sydney Sunderland, (1979) in a Founder's lecture to the American

Society for Surgery of the hand. He considered the question of whether funicular repair is feasible and concluded that it is not on a one to one basis, nor is it desirable. The aim should be to preserve naturally occurring funicular groups, as occur in the wrist, in the median and ulnar nerves proximal to their division into branches. Where no such anatomical grouping exists the nerve funiculi must be arranged arbitrarily and nerve repaired in groups of funiculi. Of all the aids to orientation—anatomical, electrophysical and histochemical—the anatomical are best.

On the question of whether funicular repair is worthwhile, he concluded "Yes" but expressed certain reservations. The procedure is time demanding; a microsurgical approach is needed; there is a risk of devascularising nerve ends by mobilising fasciculi and sutures in the interface produce fibrosis. He advised funicular suture for nerve grafting to maximise entry of axons into fasciculi and in the replantation surgery but thought it had a limited place in end to end suture where an epineural suture had the advantage of better axial alignment, less interference with ends and the ability to hold ends together under slight tension.

It is a mistake to think of epineural suture as a macroscopic procedure and perineural suture as an operation for the microscope. In my opinion all nerves should be repaired with magnification, since the features essential to matching cannot be seen adequately with the naked eye: the obliquity of the cut, the fascicle arrangement and the vasa nervorum. Having seen and achieved matching then the apposition of the ends can be much more satisfactorily achieved under magnification whether the sutures be placed in the epineurium, perineurium or in groups of fascicles. Further advantages of magnification are more precise haemostasis and the ability to use finer suture material. Whether this achieves better results—only time and a scientific prospective study will tell. Certainly the trained microsurgeon will not feel that he has done the best possible repair if he has failed to use a microscope. If this is shown to be beneficial there is no reason why all cut forearm nerves should not be repaired in this way.

Any statement on the value of microsurgery in peripheral nerve work must be considered hypothetical as the world literature does not yet include any accurate comparative scientifically planned studies for obvious reasons. To select a series of homogeneous nerve injuries, for example median nerve injuries at the wrist and omit other variables such as age, type of injury would take one surgeon many years. To attempt a controlled trial of epi- v perineural suture is probably not possible since the nerves vary so much in anatomy. Techniques evolve over a period of years and it is almost impossible to define a standard technique.

Arguments of primary versus secondary nerve suture, or repair by suture versus nerve graft are unresolved, but all nerve surgery is amenable to magnification. Exploration of the brachial plexus done more frequently in Europe than in this country requires magnification for adequate inspection of the exposed plexus, excision of damaged fibres and grafting. Successful reinnervation will assume increasing importance in reconstruction to provide effective sensation in flaps or function in muscle units as in cross facial nerve grafting. The best possible nerve approximation will be the key to success.

Nerve injuries will be encountered much more frequently than vascular problems and micro nerve surgery is perhaps the most fertile field for the microsurgeon. The vascularised nerve graft combines both disciplines and may prove to be superior to free nerve grafting.

Other Applications

In other specialties such as otolaryngology, ophthalmology and neurosurgery, the operating microscope has added a new dimension of achievement that none would dare regard as a luxury. The ready availability of microsurgical instruments and expertise allows the repair of many structures that have been often regarded as impossible such as the parotid duct, tear duct or lymphatic vessels. In genito-urinary surgery fallopian tube exploration and repair is now a practical proposition. To enter the realm of speculation would magnification reduce the fistula rate in hypospadias? Would the microscope be of value in cleft palate surgery? The illumination certainly would be helpful and much could be learned about cleft lip and palate anatomy.

The "spin-offs" of microsurgery are many. We have been forced to acquire a better understanding of flap blood supply. The quest for suitable donor sites has led to the discovery of a whole range of tissues with an axial vascular pattern and has stimulated the definition of myocutaneous flaps, muscle flaps and compound flaps.

No surgeon who has watched a replanted segment turn red, white or blue can fail to appreciate the significance of these colour changes in his pedicle flaps. Perhaps blue and dying pedicle flaps could be saved by a few well placed microvenous grafts?

There has been a striking re-awakening of interest in cadaveric dissection for anatomical investigation and operation rehearsal. Also, it must be conceded that the need to gain technical experience by operating on animals has introduced a new aspect into British surgery.

Finally, microsurgery has provided a common bond between young consultants through the medium of a Microsurgical Travelling Club. We must conclude that the microscope allows us to perform operations not possible or not satisfactorily done without magnification. Microsurgery must become an essential part of the training of all plastic surgeons. The vision of a decade ago must not be forgotten in the face of a few "teething troubles". The reconstructive possibilities of free transfer of the body tissues are limitless. Let us be prepared for the day when the fantasy becomes a reality: the suppression of immunological rejection.

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