organisms carried in the patient's nose. The established nasal carrier must also represent a potential source of staphylococci from which neighbouring patients might acquire both nasal carriage and wound infection. It has been demonstrated that the phage type of staphylococcus acquired in the 41 patients who entered hospital free from nasal carriage follows the number and distribution of established nasal carriers of the same phage type in the ward during each weekly period. Similarly, the acquisition of nasal staphylococci in the same group of patients also follows the distribution of infected cases in the ward.

The concentration of infected patients and nasal carriers in the ward dressing-room leads to the demonstrated contamination of this room, which, in addition to the ward, may represent a potent source of organisms for the development of further wound infections and even of more nasal carriers, although the time spent by the patient in a dressing-room is very short in comparison with the time spent in the ward.

Nasal carriage of staphylococci by doctors and nurses has not been of importance in this investigation.

The close association between major sources of staphylococci (infected patients and established nasal carriers) and the acquisition of nasal organisms, and between nasal carriers and the development of wound infection, must, at least in this survey, implicate the ward as the preponderant source of infection, whether actual implantation of organisms occurs in theatre or post-operatively.

Summary and Conclusions

A retrospective and prospective survey has demonstrated the frequency of staphylococcal infections in a male general surgical ward and has shown the importance of nasal carriage of staphylococci in the production of wound infection. The major sources of organisms in the development of wound infection and the acquisition of nasal carriage appeared to be the staphylococcal-infected patient and the established nasal carrier. Isolation of the infected patient and treatment of the nasal carrier would therefore seem to be the prime steps in the control of such endemic staphylococcal infection. Recent reports indicate the facility with which control of nasal carriage may be achieved by such topical antibiotics as framycetin sulphate ("soframycin") (Stratford *et al.*, 1960).

These manœuvres would not preclude the necessity for attention to other methods of passive staphylococcal transfer to which so much importance has been attached in the past, and continued vigilance must be observed in dressing techniques, the cleaning and ventilation of wards, and rigorous theatre asepsis.

We wish to acknowledge our indebtedness to Professor A. G. R. Lowdon and the surgical staff of the professorial surgical unit, Royal Victoria Infirmary, and to the members of the Departments of Bacteriology in the Royal Victoria Infirmary and the Medical School, King's College, Newcastle upon Tyne, for their enthusiastic co-operation in this investigation.

REFERENCES

- Anderson, E. S., and Williams, R. E. O. (1956). *J. clin. Path.*, **9**, 94.
 Blowers, R., Mason, G. A., Wallace, K. R., and Walton, M. (1955). *Lancet*, **2**, 786.
 Foster, W. D. (1960). *Ibid.*, **1**, 670.
 Lowbury, E. J. L. (1960). *Brit. med. J.*, **1**, 994.
 Miller, A., Linton, K. B., Gillespie, W. A., Slade, N., and Mitchell, J. P. (1960). *Lancet*, **1**, 310.
 Mitchell, A. A. B., Timbury, Morag C., Pettigrew, J. B., and Hutchison, J. G. P. (1959). *Ibid.*, **2**, 593.
 P.H.L.S. (1960). *Ibid.*, **2**, 659.
 Shooter, R. A., Smith, M. A., Griffiths, J. D., Brown, Mary E. A., Williams, R. E. O., and Jevons, M. Patricia (1958). *Brit. med. J.*, **1**, 607.
 Stratford, B., Rubbo, S. D., Christie, R., and Dixon, Shirley (1960). *Lancet*, **2**, 1225.
 Williams, R. E. O., Blowers, R., Garrod, L. P., and Shooter, R. A. (1960). *Hospital Infection*. Lloyd-Luke, London.

LONG-TERM RESULTS OF SPLIT-SKIN GRAFTING IN FINGER-TIP INJURIES

BY

F. J. MOYNIHAN, M.B., F.R.C.S.

Senior Registrar, Orthopaedic Department, Guy's Hospital, London

The problems presented by injuries to the terminal segments of the fingers have been discussed and examined on many occasions (Robins, 1954; Tempest, 1955; Reid, 1956; McCash, 1959; Flatt, 1959; Ely, 1960; and others).

The indications and claims for the various methods employed are numerous and conflicting, but condemnation of the use of the Thiersch graft has been almost unanimous. However, the fact must be faced that the alternative methods advocated demand a varying degree of surgical skill. The young and, maybe, inexperienced casualty officer called upon to treat these injuries may feel himself inadequate to embark on a plastic procedure of some magnitude in a casualty department. The Thiersch graft, which he could manage, has been so repeatedly condemned that he may be deterred from using it. Against this background the long-term results of this method of treatment have therefore been surveyed.

The following figures give some indication of the incidence of terminal segment injuries. Approximately 20,000 new patients a year are seen in the casualty department of Guy's Hospital. These include about 2,000 open injuries of the hand, of which 1,200 will require suture. Of these 2,000, 55% are lacerations involving the terminal segments of the fingers and approximately 100 to 150 of these cases will be amputations involving bone and/or pulp. If these figures are translated into national figures of casualties it will be appreciated that finger-tip amputations are a major source of casualty attendance, and as they are suffered, in the main, by working people, their importance cannot be overemphasized.

Treatment

Treatment of these bone and pulp amputations of the terminal segments of the fingers presents the casualty officer with a recurring problem. The choices open to him are: (1) the strict "do nothing" therapy, allowing the wound to granulate; (2) further shortening of the finger in order to obtain flaps for immediate closure; (3) repair by thenar or cross-finger flap; (4) resuture; (5) Wolfe grafting; and (6) split-skin grafting.

A complete *laissez faire* policy is mentioned only to be condemned. A slowly granulating wound of the terminal segment results in prolonged disability.

Further shortening of the finger is probably the treatment of choice in amputations involving more than 50% of the bone and soft tissue of the terminal segment,

particularly in manual workers, to whom rapid healing and early return to work have a greater value than on cosmesis. However, in the case of less severe injuries further amputation may be a high price to pay for what, in many cases, is a limited soft-tissue injury.

The construction of a thenar or cross-finger flap is, as has been stated, an operation which requires most careful attention to detail, good facilities, and time. If these operations are to be performed as emergencies on an out-patient basis it is the last-named which may be in shortest supply. Admission to hospital is often difficult to arrange in units handling many emergency cases.

Re-suture of a portion of amputated pulp may be successful, particularly if the injury is a clean cut and the amputated piece is clean and is carefully cleared of fat.

The use of full-thickness free grafts, as advocated by Robins (1954) and McCash (1959), is satisfactory if facilities and skill are adequate. The failed "take" of a Wolfe graft with its thick black slough, which may take many weeks to heal, is familiar to all who employ this method.

The final alternative is split-skin grafting. The value of this has been variously assessed. Tempest (1955), Reid (1956), and Flatt (1959) have condemned split-skin grafts as unsuitable for pulp and bone amputations. Criticism has been directed to their insensitivity and instability, and for these reasons thenar or cross-finger flaps have been recommended. These, however, are not without their complications of sepsis, stiffness, and failed "takes," especially when performed as emergency procedures, and for this reason it has been the practice at Guy's Hospital, for a number of years, to use split-skin grafts as the primary repair in injuries requiring grafting.

A late survey of these cases has been made in an attempt to establish: the long-term results of such grafts with regard to stability and sensitivity; the period off work as a result of injury; the justification, or otherwise, of the use of a simple technique within the capacity of relatively unskilled staff; and the place of this method in the treatment of terminal segment injuries.

Clinical Survey

The material available comprised the notes of 100 patients. These cases were selected only because they had been referred to the hand clinic for follow-up and their documents were available. Obviously, over the period of time concerned (1955-60) there were many more injuries grafted; in fact, the average is about two a week. A large number of the simpler graftings and those rapidly successful are never seen in the hand clinic. On the other hand, those cases of multiple or more severe injuries will be admitted to hospital. Thus the cases reviewed are, if at all, biased towards the more severe or complicated injuries that are suitable for out-patient treatment.

Of these 100 patients, 63 were interviewed or replied to a detailed questionnaire. The follow-up can be regarded as satisfactory, bearing in mind the large percentage of casual labourers employed in the locality. Of the 37 who failed to attend, 20 could not be traced.

The operation is performed under local anaesthesia, 2% lignocaine is used both round the donor area, which is marked out, and as a ring block to the finger(s), and

a tourniquet is applied. Antibiotics are not used unless there is a positive indication. The donor site chosen is the volar surface of the forearm in males and the outer aspect of the thigh in females. In no cases were complications noted from these "sites," though keloid formation has been reported by other writers.

Careful débridement is carried out. If bare bone is exposed a covering of pulp is obtained either by shortening the phalanx or by removal of part of the palmar cortex and medulla, thus preserving the length of the digit and the nail-bed. The graft is sutured into place and a non-adherent dressing applied. The patient reports the following day and again at five days. If all is well he is next seen at 10 days, when the dressing is gently removed, the sutures are taken out, and a protective dry dressing is applied.

The distribution of the injuries is shown in Table I. It can be seen that injuries of the ring and little fingers of the dominant hand are infrequent, whereas on the

TABLE I.—*Distribution of Injuries*

	Thumb	Index	Middle	Ring	Little	Total
Dominant hand	12	11	18	5	2	48
Non-dominant hand	11	14	10	8	9	52

non-dominant hand the index finger is most often injured and the other fingers are more or less equally affected.

Of these 100 injuries 63 were relatively clean-cut and 37 were crush or untidy injuries. Broadly speaking, they were classified, ranging from the least to the most severe, as follows: full-thickness skin only in 13, mainly tip of pulp in 34, volar pulp in 22, with loss of bone in 31. Primary healing was probably obtained in 67; there was a partial take in 16, and complete failure resulted in 17. The reasons for failure could not always be accurately adduced from the notes, but in only a small percentage was frank sepsis the cause. The majority of failures were no doubt due to bleeding and subsequent haematoma formation under the graft or, as has been suggested by Lowden, to the graft being too thick and approaching a full-thickness graft.

The time off work was up to three weeks for 46 patients, up to four weeks for 21, up to six weeks for 17, and six weeks or longer for 11; one patient had retired and in four instances the time off work was not known. That is, approximately 67% had returned to their full job—often a heavy one—in less than four weeks. The usual practice when the graft is healed is to give the patient lanolin to apply to the surface and to advise him to wear a finger-stall for protection during the first few weeks of working.

If necessary, physiotherapy is given at the end of the second week, but in none of the cases seen at interview or questioned was there evidence of finger stiffness.

Follow-up

A complete or nearly complete assessment was possible in 63 cases. The following points were investigated: (a) the state of the graft with regard to texture, incorporation, pigmentation, liability to bleed or crack, and sensitivity to temperature changes; (b) the presence or absence of tenderness; (c) the level of sensitivity and everyday use of the finger; (d) the condition of the nail where relevant; and (e) the assessment of the patient.

State of Graft.—In 44 of the 63 cases the graft was supple and in many it was well incorporated and barely visible. Eight were typified by the presence of linear cracks, but they were often a permanent feature and not associated with bleeding or ulceration. Puckering of the scar was found in seven, and in eight the graft was obviously thin and potentially unstable. In one or two cases very definite improvement of pulp contour had occurred during the months following the injury. In other cases the graft had obviously contracted, causing the general contour to be slightly flattened. In some cases the only obvious graft visible appeared to be a little puckered skin at the apex of the nail (Figs. 1 and 2). Seven of the 63 patients complained that the graft was sensitive, particularly to cold weather or cold water, when it became painful.

Tenderness.—This was present in 27, but in 29 there was no tenderness. It has been pointed out by Lowden that tenderness is most likely to occur in cases where the graft is adherent to bone or where the pulp is thin. This observation is confirmed; and 11 of the 27 had

FIG. 1.—Appearance of stable grafts on tips of index and middle fingers.

FIG. 2.—Upper finger shows the slight shortening of the pulp after injury with loss of pulp and subsequent Thiersch grafting.

had amputations involving bone and a further three had had injuries in which bone was exposed. On the converse side 11 with amputations involving bone were not tender, so that split-skin grafting was not contra-indicated; but every effort should be made to cover the exposed bone with as much pulp as is practicable. It should also be noted that this tenderness was not, by any means, either incapacitating or permanent in the majority of cases. In many it was apparent only if the graft was knocked or subjected to considerable pressure.

Level of Sensitivity.—This was determined by testing light touch, two-point discrimination, and the efficiency in picking up small objects. These tests had limitations and were open to criticism. Firstly, in some cases the limits of the graft were very difficult to determine with accuracy. Secondly, two-point discrimination appeared in some cases to be a measure of pulp pressure rather than stereognosis. This point has been discussed by Clarkson (1955). The picking up and handling of small objects as a test of sensitivity has been advocated by Moberg (1958). This is a fairly good test when applied to the thumb and index finger, and possibly to the middle finger, but is of doubtful value when applied to the ring and little fingers. Also, as was pointed out by Brock (personal communication), if one observes these patients carefully they will often be seen to use the thumb or finger so that the area immediately adjoining the graft is brought into use rather than the graft itself. In fact, the most consistently reliable test was the patient's own comment. Those who said the graft felt numb or funny or different or had noticed that they fumbled, were giving the most accurate answer—that is, the value of sensation in the graft in everyday use. Of the 63, 22 stated that the graft was numb. The remainder classified the sensation as normal and had sensation to light touch, though finer tests showed it to be deficient.

Condition of Nail.—The commonest deformity noted was curving of the nail where the tip pulp was deficient and unable to support the nail. This actually afforded some measure of protection, although some patients complained that the tip of the nail tended to catch and was easily lifted from its bed and that they were obliged to keep the nail cut short. Chronic ingrowth of the nail into the nail-bed was not seen in its established form in these patients, though one patient had had a radical excision of the nail-bed on this account.

Assessment of Patient.—A case was classified as a success or failure on the following criteria. As a failure when the patient was dissatisfied; the patient failed to make use of the finger normally; the graft was unstable, or bled or cracked easily; the graft was tender and/or numb to the extent that it was a handicap. As successful when the patient was completely satisfied, the finger was used normally, and the graft was stable.

The success/failure ratio was: 46 successes, 13 failures, and 4 requiring secondary surgery.

The reasons for the four failures for which secondary surgery was necessary were: two failed "takes," one case complicated by osteomyelitis necessitating more proximal amputation, and one complaint of insensitivity of the digit.

Of the 13 failures without secondary surgery the analysis showed 10 clean cuts and three crush cuts. Of these, six were finger-tip injuries, four amputations

involving bone, and three volar pulp injuries. The reasons for failure were one or more of the following:

Instability with tendency to crack and bleed	..	5
Numbness	..	7
Tenderness	..	7

Nine of the patients were doing work involving tool-grasping and four were heavy labourers. Thus neither the type of injury or its severity nor the patient's work appeared to be particularly significant, but it was noted that three had the right thumb involved, four the right index finger, and three the left index finger. Thus, if these three plus the left thumb are regarded as the most important digits, 10 out of 13 patients had these digits involved.

Further analysis did not reveal any other significant factors to assist in determining in advance whether this procedure would be suitable, but perhaps investigation of a larger number of failures would be of value. The length of follow-up in all cases is shown in Table II.

TABLE II.—*Length of Follow-up*

6 years in	..	3 cases	3 years in	8 cases	1 year in	..	27 cases
5 "	"	7 "	2 "	8 "	Less than 1	"	
4 "	"	8 "			year in	..	2 "

Discussion

From this survey certain points emerge which warrant further discussion and elaboration.

In every casualty procedure one unalterable factor is the casualty officer. In many hospitals the staff will be junior and relatively inexperienced; therefore, any method employed should be simple with regard to technique, be predictable in its result, and be associated with a minority of complications. Split-skin grafting is most suitable in this context, and thenar or cross-finger flaps are most unsuitable. The majority of the operations of this survey were carried out by senior dressers—that is, students in their final year: this, incidentally, provides an excellent training method in teaching hospitals.

The result is predictable in that approximately four out of five results are satisfactory. The only major complication encountered was one case of osteomyelitis. The most frequent immediate complication is failure of "take," and this does not preclude an immediate second attempt.

In the event of long-term failure, the patient may be admitted to hospital and a definitive repair by appropriate flap carried out under ideal conditions. In our cases the task has in no way been aggravated by preliminary split-skin grafting, and the only criticism that may be levelled is one of delaying the patient's return to work. In fact, only 6% of patients required further surgery.

The period off work in 67% of patients was less than four weeks, and in only two cases did the patient change his occupation on account of the injury. The average time off work in the case of thenar flaps will be at least four weeks and the rehabilitation of fingers, which are frequently stiff, may take longer.

The time off work does not always, of course, bear a strict relation to the severity of the injury, but in many cases is more closely related to the nature of the patient's work and to his personality. Reid (1956) found the average disability after split-skin grafting to be between seven and eight weeks, and Barclay (1955) nine weeks, compared with nine weeks for thenar flaps. Robins (1954) quoted times of seven weeks for split-skin grafts,

eight weeks for post-auricular grafts, and seven weeks for local flaps: he qualified this by stating that the cases of split-skin grafting were all relatively trivial. It is probably fair to say that the disability after split-skin grafting would tend to be shorter in that the patient can often return to work before complete healing has taken place, whereas this is not practicable where flap grafting has been undertaken.

The remaining two principal points are the stability and sensitivity of these grafts. Flatt (1959) has stated categorically that split-skin grafts have no place in the treatment of terminal segment amputations, as they never provide proper sensation and will be repeatedly damaged. He therefore advocates the use of a thenar flap. Robins (1954), for similar reasons, advocates a post-auricular graft. In his analysis of sensation to light touch he states: "Sensation to light touch is present in 55% of Thiersch grafts, in 75% of local flaps, and in 50% of post-auricular."

McCash (1959) advocates the use of a toe graft, which he states has better stability and sensitivity.

Particular attention to these points was made in the survey. More than half the patients stated that their sensation was normal, though there was a deficiency on finer testing. The patient's assessment is, no doubt, partly based on the adaptive use of neighbouring normal skin, the finger or thumb being orientated towards small objects in a slightly different manner; partly on the cerebral interpretation of deep pulp sensation; and partly on the progressive contraction of the graft, so that the final potentially insensitive area is much smaller than the original lesion. Thus in this context a thin split-skin graft is to be preferred to a full-thickness graft, which will not contract to the same extent. In the one or two cases of thenar-flap repair seen incidentally during this survey the sensation was not completely normal.

With regard to stability the vast majority of cases had stood up to many years of hard work; most of those reviewed had been grafted more than one year previously, and 34 between two and five years. During the first few weeks or even months after grafting, protection is desirable, but later stability improves; in very few cases was there persistent or recurrent bleeding or tenderness. Only 20% of the cases reviewed were failures on these accounts, and only one or two required further surgery. Many of the "failures" were not, in fact, so regarded by the patients, and any offer of further surgery was declined.

In conclusion, I would state that this form of treatment should be recommended to casualty officers as a satisfactory primary, and often definitive, treatment of these injuries, and every effort be made to teach students this simple technique during their casualty appointment.

Summary

A long-term review has been carried out of 100 cases of split-skin grafting to injuries of the terminal phalanx.

The result was regarded as successful in 80% of cases.

This is a method of treatment suitable for the casualty officer to apply.

I thank the casualty officers, Drs. A. Horner, A. Cooper, K. Hubble, J. Hills, and B. Batten, and Miss Daley, secretary to the department, for their help; also Mr. P. Clarkson,

accident surgeon, Guy's Hospital, for his advice and assistance.

Part of this was read as a paper at a Meeting on Surgery of the Hand held at the Royal College of Surgeons on November 19, 1960.

REFERENCES

- Barclay, T. L. (1955). *Brit. J. plast. Surg.*, **8**, 38.
 Clarkson, P. (1955). *J. Bone Jt Surg.*, **37A**, 521.
 Ely, J. F. (1960). In *Transactions of International Society of Plastic Surgeons, Second Congress, London, 1959*, edited by A. B. Wallace. Livingstone, Edinburgh.
 Flatt, A. E. (1959). *Care of Minor Hand Injuries*. Kimpton, London.
 McCash, C. R. (1959). *Brit. J. plast. Surg.*, **11**, 322.
 Moberg, E. (1958). *J. Bone Jt Surg.*, **40B**, 454.
 Reid, D. A. C. (1956). *Brit. J. plast. Surg.*, **9**, 11.
 Robins, R. H. C. (1954). *Brit. J. Surg.*, **41**, 515.
 Tempest, M. N. (1955). *Brit. J. plast. Surg.*, **7**, 153.

Preliminary Communications

Closed-circuit Perfusion of Liver Utilizing an Extracorporeal Circulation

During the last three years much interest has been aroused by the therapeutic opportunities resulting from the application of closed-circuit perfusion techniques to the chemotherapy of malignant disease. Creech and his colleagues published the first and numerous subsequent authoritative papers on this subject.^{2-6 9-15} Others have reported the results of their research and clinical trials.^{8 16-19}

The majority of chemotherapeutic compounds available for cancer suppression act directly on proliferative cells in an entirely non-specific fashion and are allied to those drugs used to achieve paralysis of immune mechanisms. Closed-circuit perfusion permits of the safe administration of high concentrations of these cytotoxic agents by confining their distribution to the tumour and its immediate environment. The hazardous side-effects of systemic administration, notably bone-marrow destruction, are therefore avoided. On theoretical grounds it seems reasonable to suppose that disturbance of "host resistance" will also be minimized.

The practical application of closed-circuit perfusion is limited by the local tissue resistance to the dose of the particular chemotherapeutic agent used and by the percentage loss of the perfusate to the systemic circulation. This latter factor is of the greatest importance when long-acting compounds are perfused, and in most sites tends to increase proportionately with the duration of the perfusion.

Possible perfusion circuits have now been elaborated for many areas of the body.^{1-7 9 10 12 13 15 17-19} The liver presents a number of unique problems in the construction of such a circuit, the most important of which may be listed as follows: (1) the dual afferent blood supply, (2) difficulty in precise and complete collection of hepatic venous blood, and (3) the necessity of diverting the portal blood flow during liver perfusion to prevent the haemodynamic effects of blood pooling in the portal-vein "watershed."

Techniques of liver perfusion have been described by others,^{1 7 15 17} but we would like to record our own solution to the above problem, which we have tested successfully in the experimental animal.

METHOD

A double catheter (Fig. 1) is passed through the right atrial appendage across the cavity of the atrium into the inferior vena cava and manipulated until the catheter with the larger lumen extends from the supra-diaphragmatic portion of the inferior vena cava to a point below the liver (Fig. 2). The distal end of the catheter with the smaller lumen now lies in that portion of the inferior vena cava draining the hepatic venous blood, the proximal end passing to the exterior across the cavity of the right atrium. By the accurate placing of temporary ligatures around the inferior vena cava (Fig. 2, ligatures 1 and 2) that portion of the inferior vena cava receiving the venous drainage of the liver is completely isolated and drains exclusively into the catheter with the smaller lumen, the catheter with the larger lumen permitting free passage of the remaining inferior vena caval stream to the right atrium.

FIG. 1.—Photograph of double catheter with second catheter used for portacaval bypass.

FIG. 2.—Diagram of closed perfusion circuit of the liver.