Late Results of Successful Replantation of Upper and Lower Extremities

M. NASSERI, H. VOSS

From the Department of Surgery, Free University of Berlin, Westend, Berlin 19, Spandauer Damm 130, Germany

DURING the last 10 years only a small number of successful replantation of extremities severed by trauma have been reported.[1,6,7,11] The importance of this procedure is not only the immediate success of the operation but above all the late results of the replantation. In our opinion this success depends on the precise and accurate reconstruction of the injured anatomical structures during the first operation. There are still differences in opinion among authors concerning this special operative procedure, the type of neural suture used and the time at which the severed nerve endings are joined.[5,8,10]

Therefore the two patients, in whom we have replanted a leg in one and an arm in the other after amputations by trauma and we have followed 5 and 2 years respectively, may contribute to the solution of this problem. The second patient is of special interest because the amputated arm was lost for a 2-hour period.

Case Reports

Case 1. J. G., a 54-year-old man was admitted to Berlin-Neukölln City Hospital on October 28th 1964, approximately 30 minutes after a train accident in which the right thigh was amputated just above the knee joint. Only a small lateral skin bridge remained intact (Fig. 1). There was also a severe laceration of the left thigh with heavy damage to soft tissue as well as a fracture of the femur. Both wounds were dirty and covered with oil and sand. The wounds were debrided and cleaned with physiological saline solution and penicillin. Circulation was restored 3½ hours after amputation through anastomoses of the popliteal vein and artery. The continuity of both nerves—internal and external popliteal—was reestablished by primary suture. Alignment and stability of the femur was attained by balanced traction. Musculo-fascial layers were repaired with mersilene or catgut and the severely damaged skin was closed.

Postoperative Course

Circulation in the thigh was normal and remained unchanged. Marked edema in the first 2 weeks disappeared completely. Galvanic stimulation of the denervated muscle groups was begun on the 2nd week after injury and was continued daily for more than 1 year. The necrotized area of skin in the knee hollow was replaced by skin autografts during the 6th week. Physic therapy with passive motion of joints was started during the 4th week. An aseptic fistula in the knee hollow caused by a number of sequestered bone chips closed promptly after the extirpation of the bone fragments. The stability of the femur allowed us to remove the extracutaneous fixation and traction after 12 weeks.

Return of Function

The first active motion in the flexor muscle group was observed 14 months after injury. Between the 14th and 20th months there was a complete return of motor and sensory function of the tibial nerve.

Active motions of the flexor muscles and the small plantar muscles and the regaining of partial sensibility permitted free movement and weight bearing on the leg. About 1½ years after the accident the patient could walk without any help (Fig. 2).

Present Status

The patient is currently able to walk and to care for himself. The function of the leg is restrained because the peroneal nerve is still paralyzed. This loss can be partially compensated by orthopedic shoes. All functions of the tibial nerve can be seen. There is no shortening of the leg and no severe dystrophy.

The active movement in the knee joint is 175° extension and 110° flexion. In the foot joint a plantar flexion of 30° is possible but no active dorsal extension. The pronation and abduction of the foot is not possible because of the paralysis of the peroneal nerve. In the region innervated by the fibular nerve there is no sensitivity on the dorsal surface of the foot.

Case 2. R. K., an 8-year-old boy was brought to the University Hospital of Berlin-Westend on the 24th of June 1969, about 40 minutes after falling from a moving train in which case the right arm had been amputated completely above the elbow joint.

There was also a deep tangential wound at the right chest side with fracture of ribs and an open pneumothorax (Fig. 3). Two hours after admission the police succeeded in finding the severed arm near the railroad track and brought it to the hospital. The arm was immediately preserved in ice immersion to lower the

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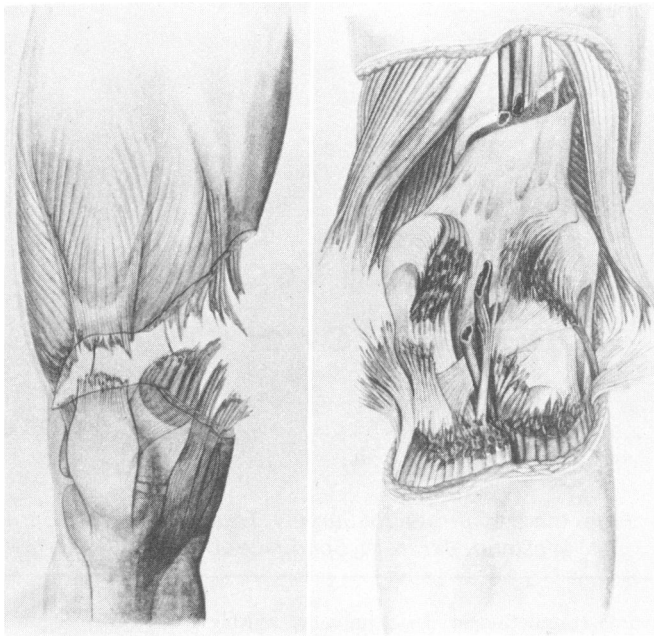

FIG. 1. The drawing shows the nature of the amputation. Only a lateral skin bridge remained intact.

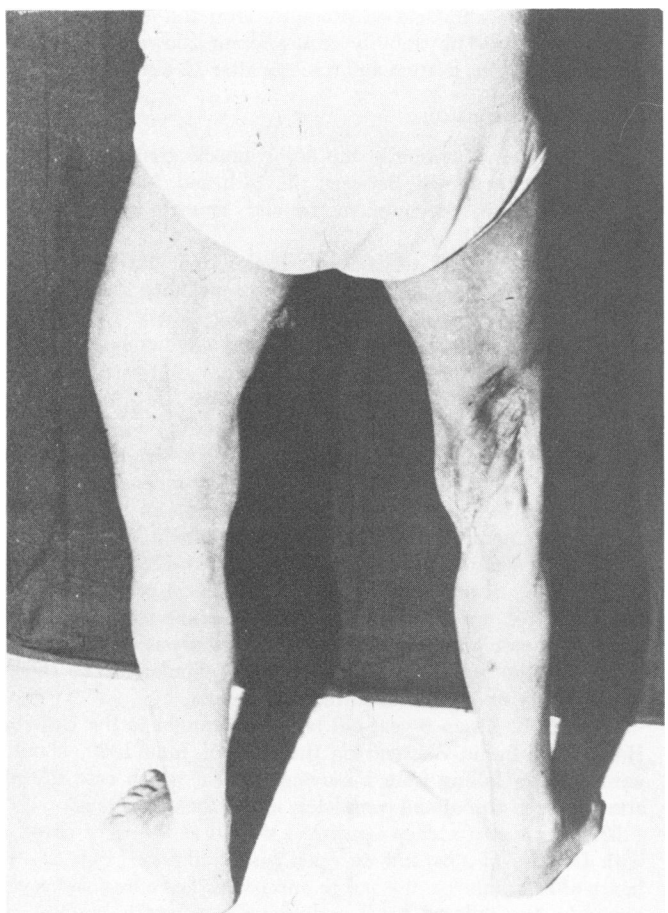

FIG. 2. Five years after the accident the patient is able to stand and to walk without any help.

FIG. 3. Appearance of the boys right side on arrival in the hospital. The stump of the right arm is left on the body. The right chest is opened by a deep tangential wound.

tissue temperature to 10°C. During this period both wounds were debrided. The next step was the repair of the comminuted fraction of the humerus, the fragments of which were fixed with screws and a plate. Anastomoses of three small veins (two along the brachial artery and the basilic vein) was followed by arterial anastomoses. Circulation was restored 5 hours after injury. Following the advice of neurosurgeons we did not perform a primary nerve suture. The operation was terminated with fixation of the triceps muscle tendon to the olecranon, suturing of the severely damaged flexor muscle group and covering of the wound with the damaged skin (Fig. 4).

Postoperative Course

Twenty four hours after operation, congestion and cyanosis of the arm occurred. The clinical symptoms of thrombosis of the venous anastomoses were verified during reoperation and the venous anastomoses were redone. After this event we heparinized the patient with 1 mg./Kg./6 hours for 5 days. The necrotized skin area was replaced with autotransplants 4 weeks after injury. Secondary nerve repair was done 12 weeks later. The procedure was extremely difficult because of severe keloid scar. The continuity of the proximal end of the median nerve could be isolated and communicated with the distal end of a nerve, which was embeded in the scar mass. It was not clear at this point if the distal end was the median or radial nerve. The highly shortened proximal end of the radial nerve was unfit for anasto-

FIG. 4. The end replantation of the arm.

moses. The continuity of both above mentioned nerves was attained after resection of neurinoma. Recovery of neural function seemed to be highly improbable.

Return of Function

Galvanic stimulation and physical therapy were continued after the 4th week. The first active motion which could be seen 6 months after neural repair was extension of the hand and sensibility in the forearm (Fig. 5). Flexion and extension in the elbow joint increased rapidly and remained only slightly limited by scar contraction. The temperature sensibility returned on the posterior surface of the forearm and hand but was absent on the volar surface of the fingers causing a slight scalding with boiling water 6 months ago.

Present Status

Severe keloid has developed in all scars, especially in the upper arm extending to the forearm. The right forearm has the same color and length as the left forearm except that it is slightly thinner (Fig. 6). Sensibility has returned to the posterior and anterior surface of the forearm and the dorsal surface of the hand but it is absent on the volar surface of the fingers. Active motion of the elbow joint is nearly unrestrained. All functions of the radial nerve are evident (Fig. 7). One and a half year after neural suture we could detect an active flexion of I–III fingers. The boy can pick up minor objects with the three fingers as well as carry his brief case (Fig. 8). He is able to ride his bicycle and to hold on to the handlebars with only his right hand. There is no return of function of the thenar and hypothenar muscles now in the function of the ulnar nerve.

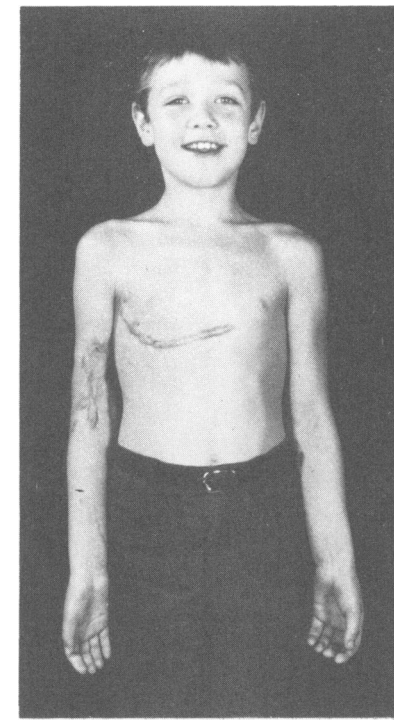

FIG. 6. The patient 24 months after replantation. Severe keloid has developed in all scars.

Discussion

The late results of our two replanted extremities demonstrate clearly that the efforts to preserve an extremity amputated by trauma can lead to full or partial restitution of function. The extent to which the replanted extremity regains its function depends upon the degree of tissue damage and also on the primary operative procedure. Several factors which are of importance are discussed.

Time Factor: The quick restitution of circulation is important to avoid an ischemic muscle contraction and to attain proper function of the extremity eventually. Circulatory function can be attained promptly by reducing the ischemic time during the primary operative procedure as well as by prolonging the tolerance time against hypoxia with technics of preservation. In normothermia, extremities have been replanted successfully 6 hours after

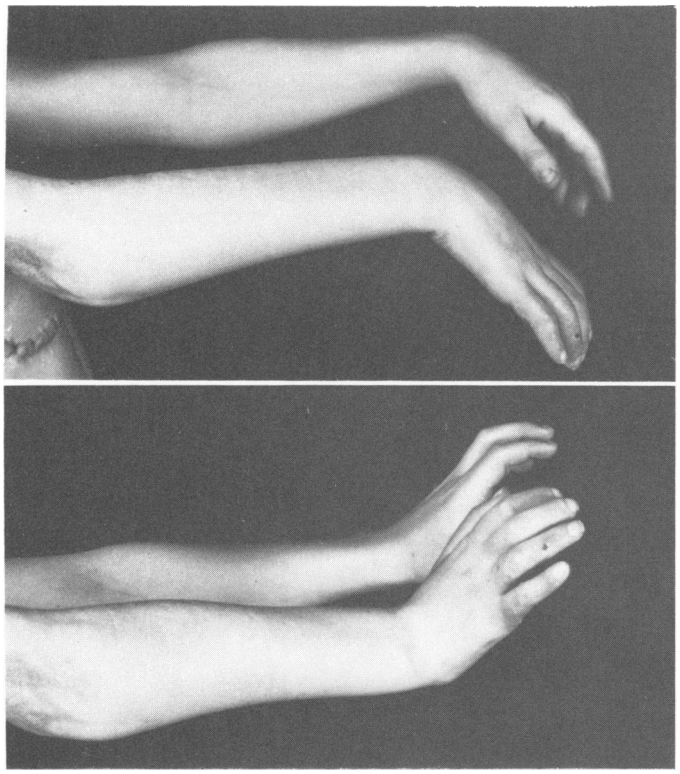

FIG. 5. Nine months after the secondary neural repair the boy can actively extend the wrist.

FIG. 7. Twenty four months after replantation. All functions of the radial nerve have returned.

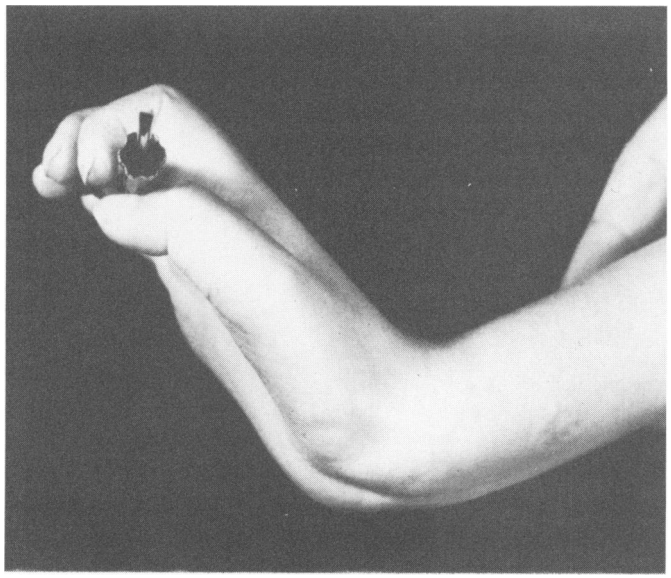

FIG. 8. Beginning active flexion of the thumb, the index and middle finger: minor objects can be picked up.

amputation has occurred.[1] Some authors state that the tolerance time after interruption of circulation in the extremities is between 8–12 hours.[4] This time can be extended to 18 hours with surface hypothermia by immersion in ice water.[6] The ischemic time in the second patient was 5 hours by hypothermia. In both patients no ischemic muscle contractions could be seen. Debridement of necrotized soft tissue and covering of skin lesions with skin autografts is important to avoid infection and serious contraction by scar. In both patients the skin lesions were primarily covered with severely damaged skin that was replaced some weeks later by autotransplants. Because of a tendency to form keloid the second patient developed a scar contraction at the anterior surface of the elbow joint, which has to be corrected by a later operation.

Bones: Exact anatomical reconstruction and sufficient fixation of the fragments during the primary operative procedure are important to avoid pseudarthroses postoperatively. The osteosyntheses can be achieved by nailing as well as by plates and screws. Only in special instances as with our first patient can an extracutaneous fixation with traction be used. Some authors recommend a shortening of the bone of 2–4 cm. to eliminate tension in the anastomoses of nerves and vessels.[4,5,6] Although the growth of replanted limbs seems to be retarded, in our opinion, shortening of the bone is not necessary. No shortening of bones was done in either of our patients and all anastomoses were constructed without tension.

Vascular: Adequate arterial anastomoses as well as sufficient venous anastomoses determine to a large extent the early and late results, especially since the lymphatic vessels are interrupted during the first postoperative period. Small venous anastomoses have a tendency to be thrombotic and it became necessary to heparinize the patient as in our second case. From the three venous anatomoses that were performed during the first operation, only the basilic vein remained patent and provided venous outflow (Fig. 9). Severe swelling of the arm and leg disappeared after 2 weeks probably due to the development of new lymphatic vessels.

Nerves: The type of neural suture, the time of nerve repair and the activation of the neuro-muscular system during the postoperative period are very important to the ultimate outcome. The most discussed issue is the

FIG. 9. Angiogram of the arm 3 months after replantation showing the artery and the venous drainage only through the basilic vein.

time of nerve repair. Although some authors favor a secondary neural suture,[3] most investigators agree that a primary suture is particularly suitable for the replantation of upper extremities. Primary sutures facilitate the anatomic preparation of the nerve ends and eliminate the need for extensive resection of nerve ends by secondary suture because of neurinomas. Malt[6] reports two cases of replanted upper extremities. In the first case the functions of the ulnar and median nerves returned 20 months after primary neural suture. In the second case, 8 months after operation, only the functions of the radial nerve were noted. In our first patient the functions of the tibial nerve could be observed 1½ years after primary neural suture. Conversely, the peroneal nerve showed no signs of regeneration. Only one replantation of a lower extremity has been reported by Close and Gilbert.[2] In this instance the sciatic nerve was intact. Therefore a comparative study with our results is not possible.

The secondary neural suture in our second patient which was done 12 weeks after the accident only with the ulnar and median nerve was extremely difficult. The upper ends of the ulnar and median nerve which had been marked during the first operation could not be prepared and adapted to the anatstomoses because of the scar tissue. There existed some doubt during the operation whether the distal end of the median or radial nerve could be anastomosed to the proximal end of the median nerve. Six months after the secondary suture a partial return of sensibility and motor function with active extension in the hand joint has occurred. Therefore, it is certain that the distal end of the radial nerve has been anastomosed to the proximal end of the median nerve.

The degree of function that has returned 2 years after the secondary neural suture can not be explained completely. The function of the radial nerve has returned completely in addition to a definite active flexion of the first three fingers enabling the lifting of minor things. During the suturing of the nerves only the ends of the ulnar nerve and probably the proximal end of the median nerve with the distal end of the radial nerve were connected, therefore, it can be assumed that the neuromuscular innervation is abnormal.

Although in both instances a partial return of function in the extremities has been achieved we believe that a primary neural suture must be preferred for following reasons:

a) the preparation of the nerve ends in the extensive scar tissue is difficult,

b) the resection of the terminal nerve ends leads to a shortening of the nerves,

c) the results of a secondary neural suture are not as successful as a primary neural suture.[4,12]

In the upper extremity the ulnar nerve and in the lower extremity the peroneal nerve seem to have the least ability to regenerate. Another factor necessary to achieve good function in the replanted extremity is the activation of denervated muscle groups during the first year until the reinnervation of the muscles occurs. This is important to avoid atrophy caused by inactivity. The reward for these difficult and time consuming efforts is the restitution of good function of the limb, the rehabilitation of the patient, and the elimination of any need for a prosthetic device.

Summary

The ultimate results of successful replantation of upper and lower extremities are reported. In the first case a leg of an adult man was almost completely amputated. Five years after primary neural suture the leg has good motor and sensory reinnervation. The man is able to walk without any help. In the second case the arm of a young boy was severed. Two years after secondary neural repair all functions of the radial nerve and a partial function of the median nerve are present.

We favor primary neural suture rather than delayed neural repair because the nerve ends can be adapted much more easily and resection of grown neurinomas is not necessary.

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