Replantation is defined as reattachment of the part that has been completely amputated and there is no connection between the severed part and the patient. In Boston in 1962 Malt successfully replanted a completely amputated arm of a 12-year-old boy. Komatsu and Tamai reported the first successful replantation of an amputated digit by microvascular technique. There are no strict indications and contraindications for replantation. It's on surgeon to explain to the patient the chances of success of viability, expected function, length of operation, hospitalization and long rehabilitation protocol. Survival and useful function in replantation of upper extremity amputations is questionable. Success depends on microvascular anastomoses, but the final function is related with tendon, nerve, bone and joint repair.

Key words: amputation, replantation, digital injury, upper extremity, microsurgery

INTRODUCTION

Replantation is defined as reattachment of an organ that is completely amputated and there is no connection between the severed organ and the patient. The first successful replantation of a severed limb was performed in 1962, by Malt and his collaborators from Boston. They replaced the completely amputated arm of a 12-year-old boy. In 1965, Komatsu and Tamai of Japan performed the first successful replantation of an amputated finger. Percentage of successful replantations varies from one author to another, oscillating between 63% and 94%. In the case of replantation of large limbs the success rate varies between 40% and 80%, but data are very heterogeneous. Success of replantation cannot be assessed only from the standpoint of the survival of the reattached body part, but rather from standpoint of the recovery of its functions. Although it is relatively helpful to compare the reattached body part with the side of the body that was not injured, it is much more helpful to compare the replanted body part with prosthesis. The works of most authors suggest that similar results should be expected. Different parameters are used to assess functional results, such as return to the previous job, muscular function, range of movement, sensory recovery, capacity to perform everyday activities and how the patient is satisfied with the results. Tamai reports excellent and good results in 72% of the patients. Jones and collaborators found good grip strength in case of patients to whom the thumb or several fingers had been replanted. Their study confirms the well-known concept that the thumb must be reattached whenever minimal conditions are met. It is considered that the more proximal an injury is, the smaller are the chances of patients to return to their previous job. Today, replanted parts without sensitivity and function are considered unacceptable. A large number of patients have limited joint movements, especially if they underwent initial joint injury and if the injury of the flexor tissues is located in zone II. Functional results, after the major limb replantation, vary and depend on the age of the patient, the level and the mechanism of injury. (Figure 1a, 1b)

Replantation results are worse in the case of amputations below the elbow, at the level of the elbow articulation or through the muscular part of the proximal forearm.

INDICATIONS FOR REPLANTATION

It is difficult to decide whether a amputated body part should be replanted or not. Before submitting the patient to a long surgical procedure and a complex rehabilitation period, we must examine very carefully how possible it is to re-establish the movement and to recover the sensitivity of the severed body part. We must take into consideration the following factors: age, severity of the injury, level of amputation, appearance of the severed body part, "ischaemia" time, general condition of the patient, possibility to collaborate during rehabilitation and the economic factor. In some cases, when several fingers have been amputated, only the least damaged finger is replanted, if the others present severe tissue destruction. For example, if the thumb and the index finger were severed and the thumb suffered a severe crush injury, it is indicated to replant the index finger in the place of the thumb, because in this way we will obtain a functional and esthetically acceptable hand. We must make any effort to save the severed thumb, practically at any level, even distally.
from the base of the fingernail, but of course, it is possible to prepare the blood vessel for revascularization. Some authors have the same stand regarding the index finger. The functional results after replanting a finger distally from the attachment of the superficial flexor are usually satisfactory, with good recovery of movement and sensitivity. In the case of adult patients, it is not indicated to replant amputations proximally from the attachment of the superficial flexor. We should consider cases such as young women, violinists, pianists etc. However, it is unlikely to obtain satisfactory functions. A very specific problem is the so-called "ring avulsions". Even if bone and tissue structures are preserved, the vascular elements may be damaged, in such a way that results are sometimes very bad. These injuries are maybe the only ones that are precisely classified, because the functional result depends on that classification. The surgeon must explain to the patient what chances the severed body part has to survive, as well as the functional result, the duration of the operation, the length of the hospitalization period and how long he/she will be absent from work.

There are no absolute indications for replantation.

1. young people, even if this is relative.
2. clean and straight guillotine amputations, with no crush components and with minimal damage of the vascular elements
3. amputations of the thumb at any level
4. ischemia time up to 6 hours for all injuries proximally at the level of the palm and 8 hours or more in the case of fingers.

We can generally say that patients with the following injuries are good candidates for replantation: (1) amputation of the thumb, (2) amputation of several fingers, (3) amputation of the hand at the level of the palm, (4) almost any amputation in the case of children, (5) amputation of the hand and the forearm, (6) straight and sharp amputations at the level of the elbow and below it, (7) amputation of one finger distally from the attachment of the superficial flexor.

Almost the same can be said about contraindications, i.e. that there are no absolute contraindications and that each patient must be assessed individually:

1. elder people
2. extensive avulsion and crush injuries, segmental injuries at several levels, ring avulsions at the level of the articulation, severe contamination of the amputated body part
3. amputations in the proximity of the shoulders, amputation of one finger proximally from the attachment of the sublimus
4. a long ischemia period, because muscles suffer irreversible necrotic changes after 6 hours. This period can be extended if the severed body part is kept at 4°C. It is considered that severed body parts that contain skeletal-muscular tissue must be replanted in a period of time between 6 and 8 hours. In such cases the risk of infection is also higher. It is considered that fingers can be replanted even after 30 hours if they were kept at 4°C. Successful replantations have been reported even after 33 hours of warm handling and 94 hours of cold preservation.
5. existence of previous deformities or damages caused by earlier injuries of the amputated body part
6. injuries of other organs and systems

FIGURE 1A
TRAUMATIC AMPUTATION AT WRIST LEVEL AND RADIOGRAPHY OF AMPUTATION

FIGURE 1B
RESULT OF REPLANTATION
7. patients with conjoined and chronic diseases, such as in the case of diabetes mellitus, rheumatoid arthritis, lupus and other collagenosis, cardiovascular diseases, malignant diseases, chronic diseases of the kidneys and the lungs, gastric ulcers etc.

8. self-destructive psychiatric patients that inflicted the injury to themselves, if the psychiatric episode cannot be stabilized, especially if it is possible that they will harm themselves again.

The amputated body part must be carefully prepared, rinsed with physiological solution and then transported in one of two ways:

1. wrap the amputated body part in sterile gauze soaked in physiological solution. Place it in a plastic bag and then in ice
2. place the amputated body part in a bag with physiological solution and then place the bag in ice

In both cases you must be careful that the body part is not in contact with the ice.

OPERATIVE PROCEDURE

It is desirable that two separate teams work in the preparation of the patient and the preparation of the amputated organ. Usually the procedure takes place in the following order: shortening of the bone and stabilization of the fracture, repair of the extensor tendons and then of the flexor tendons, suture of the arteries, nerves and veins and finally closing the wound. Some surgeons first repair the vein vessels and the arterial ones, in order to diminish the loss of blood and to keep and field free of blood for a better visualization. If a replantation is attempted at the level of the fingernail or even more distally, it will not be possible to find dorsal veins, of course. In case that the replantation of such distal part is indicated, an adequate vein drainage can be attained in at least three ways:

1. by suture the volar veins,
2. anastomosis of the distal digital artery for the proximal vein, in order to create a A-V fistula,
3. by removing the fingernail plate,
4. by using medical leeches

The replanted limb is immobilized and circulation is controlled in the post-surgical period. The hand is usually placed at the level of the heart. Antibiotics and anticoagulants are prescribed. The Heparin dose is usually 1000 i.j. per hour during the first week after surgery and is deter-mined according to prothrombine time (PT) and the par-tial prothrombine time (PTT). In case that there are bleedings, the dose must be diminished and the gauze must be immediately replaced to prevent the constriction by saturated gauzes. The rehabilitation program usually begins after three weeks.

During the postoperative period it is important to monitor the color, turgor, capillary refill and skin temperature. Monitoring methods include the measure of oxygenation and perfusion. In case that the replanted body part shows signs of vein problems, it must be elevated, while it must be lowered in case of pale stasis (sign of arterial suffering).

The room must be warm and the analgesics and sedatives must prevent the vasospasm. In case that the circulation is compromised and measures, such as administrating Heparin in the bolus or releasing the tightened gauzes or the stitches, do not improve the circulation, the surgeon should reconsider the intervention. If such a decision is taken, then it must be carried out within 4 and 6 hours from the moment when circulation was compromised.

COMPLICATIONS

They can be early complications, such as bleeding, skin necrosis, ischemia and infections, and late complications, such as unhealed fractures or insufficient healing, adhesions, formation, stiffness of articulations and delay in the recovery of nervous functions. The major limb replantation may fail because of two main reasons: mionecrosis associated with subsequent infection and failure to ensure the adequate decompression of the restored blood vessels. Any exposed vessels may be covered by appropriate soft-tissue cover. In the case of these patients, bandaging must be performed under anesthesia within 48 or 72 hours from the operations and then the devitalized muscle should be debrided.

RESULTS

The results that can be expected based on the reports of large replantation centers are:

1. recovery of the nerve, as if it were an isolated injury of the peripheral nerve
2. a range of active movement of 50% compared to the contralateral side
3. intolerance to cold, which should usually diminish after two years
4. acceptable cosmetic appearance, which is better than the amputation or prosthesis
5. best results can be expected after the replantation of the thumb, hand, injuries at the level of the wrist, as well as in the case of fingers distally from the attachment of the superficial flexor\textsuperscript{21,22,23}. (Figure 2a, 2b)

Though today the allotransplantation of composite tissues is technically possible, the replantation of the amputated body part still represents the best choice. Howe-ver, the severe damage of the amputated body part by the initial trauma can disturb the functional result of the re-plantation. In such cases, the transplantation from cadavers is considered as a viable option. Transplantation is performed in the case of well motivated and psychically stable adults, with good health condition, who had unsuccessful prostheticizing experiences or could not adapt to the pros-thesis. The further development of immunosuppressive protocols may favor the future use of allotransplantation as a method\textsuperscript{24,25}.

\textbf{SAŽETAK}

\textbf{REPLANTACIJE GORNJEG EKSTREMITETA, ŠAKE I PRSTIJA}

Replantacija se definiše kao prišivanje kompletno amputiranog dela, odnosno prišivanje u onim slučajevima gde ne postoji spoj između povredenog dela i pacijenta. 1962. godine Malt i njegovi saradnici iz Bostona su uspešno replantirali kompletno odsećenu šaku kod dvanajes-togodišnjeg decaka. Komatsu i Tamai objavljaju prvu uspešnu replantaciju amputiranog prsta mikrovaskularnom tehnikom. Ne postoje striktna indikacije i kontraindikacije za replantaciju. Hirurg mora da objasni pacijentu šanse za uspeh preživljavanja replantiranog dela, funkcionalni is-hod, dužinu operacije, hospitalizacije, kao i dugi rehabilitacioni protokol. Postizanje preživljavanja i adekvatne fu-nkcije kod replantacije gornjeg ekstremiteta je teško. Ini-cijalno preživljavanje replantiranog dela zavisi od mikro-vaskularne anastomoze, dok krajnja funkcija zavisi od re-paracije tetiva, nerava, kosti i zglobova.

\textbf{Ključne reči: replantacije, povrede šake, mikrohirurgija}

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