Critical analysis of upper limb replantations

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ABSTRACT

Objective: The authors analyze the follow-up of results in 62 adult patients who had traumatic amputations in the upper limb and who underwent successful replantation procedures from 1994 to 2004. Methods: The levels of amputation were in fingers or thumb in 48, hand in 5, wrist in 4, forearm in 2 and arm in 3 patients. All patients were treated in a rehabilitation program of specialized hand therapy. A simplified questionnaire was used to evaluate the return to work activities using the operated limb, either in the formal or informal economy, and the patient’s satisfaction rate concerning the surgical procedure. Results: It was noted that 85.5% of patients returned to some work activity using the operated limb and 96.8% of patients are satisfied with the results. Conclusions: Patients submitted to successful replantation present a high rate of satisfaction and return to work activities.

Keywords: Prostheses and implants; Upper limb/injuries; Employment, supported/statistics & numerical data; Treatment outcome

INTRODUCTION

The first successful replantation performed was reported by Malt and McKhann, in 1964. The authors managed to replant an arm that had been amputated in the proximal humerus in a 12-year-old child. In 1968, Komatsu and Tamai carried out the first replantation of a thumb using a microsurgical technique. Since then, several centers to treat patients with amputations and revascularizations have emerged in the world and they have performed a large number of surgical procedures. This has not happened in Brazil, where there is a very small number of specialized centers, thus presenting an insufficient and poor quality medical care in this sector.

Replantation is defined as the surgical procedure for complete reconstruction of arteries, veins and other structures in an amputated segment. The purpose of replantation is not only to reestablish blood perfusion,
but also to obtain the return of function in the limb\(^{(4)}\). Every patient who suffers an amputation is a potential candidate for the procedures of replantation or revascularization\(^{(5)}\).

After the trauma, the amputated area must be cleaned as soon as possible. Ideally, the amputated area should be rinsed with an antiseptic solution (while the bloody area is protected) and followed by irrigation with a large amount of saline solution. The amputated segment, after being cleaned, should be wrapped with a sterile compress (or a similar material) embedded in saline solution and placed in a sterile plastic bag (or similar). The plastic bag containing the amputated segment should be placed in a container that is able to maintain low temperatures (a polystyrene cooler box or similar device) with ice cubes. The purpose is to maintain the amputated segment under hypothermia (approximately 4°C), with no direct contact with ice, which could cause burning. The proximal segment should be washed as soon as possible, and surgical debridement should be performed at the time of reconstructive surgery. The ligation of vessels for attaining hemostasis should be avoided as much as possible. Bleeding can normally be controlled with compressive dressings. Ligation of vessels means the sacrifice of some millimeters which could be used in termino-terminal vascular microanastomoses, thus forcing the indication of grafts to promote the reperfusion of ischemic tissues\(^{(6-7)}\).

Each patient who suffers a traumatic amputation should be individually analyzed. We should always consider that the main purpose of reconstructive surgery is to obtain a viable and functional limb\(^{(8-13)}\). Some factors may influence the functional result, such as patient’s age (the younger the patient, the better is the functional result), motivation, occupation and duration of ischemia\(^{(3,5,11)}\). A normothermic ischemia for a long period may make replantation unfeasible. The striated muscle tissue may suffer necrosis after approximately three hours of normothermic ischemia. The more proximally located the amputation, the larger amount of ischemic muscle tissue involved and the shorter the duration of ischemia allowed. In a proximal amputation, the maximum accepted duration of ischemia under hypothermia is six hours, while in distal amputations this duration is up to 24 hours\(^{(3,10,4-15)}\). Replantation is always indicated in amputations of the thumb, multiple fingers, a single finger distally to the insertion of the superficial flexor muscle in the middle phalanx, hand, wrist, forearm, elbow and arm, as long as there are favorable conditions for the procedure\(^{(3,6,16-17)}\). As to the mechanism of trauma, the amputations caused by cutting instruments have the best prognosis, followed by blunt/open injury mechanisms, smashing and avulsion\(^{(16)}\). The last two mechanisms require more debridement, use of a more complex surgical technique and are associated with a worse success rate\(^{(16)}\).

When the amputation takes place distally to the insertion of the superficial flexor tendon in the middle phalanx, replantation must always be performed since it provides good function and produces an appropriate cosmetic appearance. Likewise, the amputation of multiple fingers or in cases of amputation of a finger associated with severe damage of other fingers, the replantation procedure will always be indicated to try to recover the maximum possible amount of function. In amputations of a single finger proximal to the insertion of the superficial flexor tendon, or in finger amputations caused by avulsion (such as avulsions caused by a ring), replantation must be indicated by analyzing each patient individually\(^{(3,6,16-19)}\).

As to the surgical technique, every devitalized and contaminated tissue should be carefully excised by using magnifying lenses. If not critical ischemia time is present, the surgeon can choose the best strategy for reconstruction of the structures. The most frequently used sequence is bone reconstruction (shortening or regularization with fixation), followed by reconstruction of the extensor tendons, anastomosis of dorsal veins, tenorrhaphy of flexors, anastomosis of arteries, neurorrhaphies and skin suture. In some situations, it is advantageous to perform the arterial anastomosis before the venous anastomosis since it reduces the ischemia time and allows easier finding of the veins thanks to bleeding. On the other hand, the release of arterial anastomosis before the venous anastomosis causes a larger blood loss and a more pronounced edema in the distal stump. When ischemia time is too long and viability of the replantation is critical, osteosynthesis and arterial and venous anastomosis should be carried out as soon as possible.

After debridement of all the structures, the bone should be shortened and fixed. Bone shortening is performed to promote the fixation between regular, clean and viable extremities. This procedure improves the success rate in terms of bone consolidation and decreases the tension of other structures to be reconstituted, such as vessels, nerves and tendons\(^{(3,6,10,14,17,19-20)}\). The type of osteosynthesis to be chosen will depend on the conditions of the bone tissue and the injury site. Among the most used options are the neutralization and impaction plaques, Kirschner wires, external fixation devices, threads and tension bands\(^{(21)}\). The injuries compromising a joint can be treated with a primary arthrodesis. Flexor and extensor tendons can be shortened in the same...
measurement as the bone portion trying to maintain the same muscle tension\textsuperscript{(3)}. Tendons must be reconstructed according to conventional techniques or those that provide better resistance, and tendinous adhesions should be avoided at all costs. The extensor tendons must be sutured before performing venous anastomoses. The mobility of the replanted part will depend on the quality of the muscular/tendinous structures and the evolvement of vascular microanastomosis. After debridement, it is frequently necessary to use vascular grafts for reconstruction of the segmental loss of vessels\textsuperscript{(3,5)}.

The success of replantation is intimately related to the quality of reconstruction of peripheral nerves. The technique of reconstruction of a peripheral nerve will depend on the nerve and the location involved. The digital nerves, which are oligofasciculated and purely sensitive, are usually reconstructed by means of an external epineural suture. Median and ulnar nerves have an organized fasciculated structure and can be reconstructed with an internal epineural suture. After debridement, sometimes there is a segmental loss of the peripheral nerve which requires repair with nerve grafts\textsuperscript{(5,9,13-14,16)}.

The skin should be sutured with separate stitches without tension. It is fundamental to provide protection of the cutaneous coverage of all the reconstructed structures. If necessary, we can use skin grafts or skin flaps\textsuperscript{(3,5,16)}.

The successful viability of the replanted tissues does not necessarily mean the success in terms of functional recovery of the affected limb. Many authors have worried about the functional result of replantations and the cost-benefit of this complex and expensive procedure\textsuperscript{(5,8,9,13,15,19-20)}.

**OBJECTIVE**

The objective of this study is to analyze the functional results obtained in the replantation procedures performed in the upper limb which evolved with viability, in terms of patient’s capacity to resume regular work activities using the affected limb and patient’s satisfaction rate concerning the surgery performed.

**METHODS**

From 1994 to 2004, 62 patients who suffered amputation and underwent replantation procedures were followed up. Most patients were male (51 patients). The age ranged from 19 to 61 years with a mean age of 33 years. The most common trauma mechanism was open/blunt caused by a circular saw or a similar instrument (39 patients or 62.9%). The levels of amputations were fingers or thumb in 48, hand in 5, wrist in 4, forearm in 2 and arm in 3 patients. The patients included were those who presented viable replantation and regularly attended the follow-up visits, regardless of the level of amputation, mechanism of injury and duration of ischemia. All patients were treated in a rehabilitation program of specialized hand therapy. This patient sample was followed up with the analysis, in particular, of the patient’s level of satisfaction concerning the surgical procedure and return to work activity using the operated upper limb. Such data were obtained through the use of a questionnaire during the medical visit and also through telephone contact, and it included the following questions:

1. Are you satisfied with your surgery?
2. Are you using the operated upper limb in your work activity (work in formal or informal economy)?

The follow-up period after replantation surgery ranged from 23 to 116 months with a mean duration of 84 months.

**RESULTS**

Sixty out of 62 patients reported to be satisfied with the surgical treatment (96.8%) (table 1).

<table>
<thead>
<tr>
<th>Satisfied patients</th>
<th>Dissatisfied patients</th>
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<tr>
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<tr>
<td>%</td>
<td>96.8</td>
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The two dissatisfied patients suffered amputation in the proximal area of the arm and presented a poor result concerning nerve regeneration and recovery of the sensory and motor function of the upper limb. In the sample of 62 patients who underwent replantation, 53 patients continued to do their work activities using the operated limb (85.5% of patients) either in formal or informal economy.

<table>
<thead>
<tr>
<th>With work activity</th>
<th>Without work activity</th>
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<tbody>
<tr>
<td>N</td>
<td>53</td>
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<tr>
<td>%</td>
<td>85.5%</td>
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<tr>
<td></td>
<td>9</td>
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<td>14.5%</td>
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All nine patients with no work activity are retired due to invalidity. Only two patients feel as totally
incapacitated and 7 reported that they are able to do their routine activities. The age range in this group was 42-61 years (mean of 54 years).

**Clinical cases**

![Figure 1. Amputation of the forearm by avulsion mechanism in an industrial centrifuge](image)

**DISCUSSION**

The fact that there are few reference centers for medical care of patients who suffer amputation in Brazil motivated us to analyze the population who underwent replantation procedures in the last decade. We believe it is very important to check if such patients are satisfied with the procedure, if they value the reconstructive surgery to which they were submitted to and if they are able to perform any work activity that may help their independence. All injury mechanisms and different levels of amputation were included in this study.

The amputated patients are usually on sick leave and increase the bulky lines of patients on invalidity benefits. This is a huge burden to patients and society. A successful replantation procedure may mean the return of patients to a more appropriate social contact and make patients productive to themselves, their families and society.

We had the opportunity to gather the reports from such patients throughout their clinical course and, more recently, in the last 7 months. We believe that the use of a very simple questionnaire with only two questions about the patient satisfaction and return to work activities could provide us with appropriate information to evaluate the cost-benefit ratio of such procedures. We should keep in mind that replantation procedures are long, expensive surgeries with a significant rate of complications. On the other hand, there has never been an assessment throughout time of patients who achieved successful viability. In several series, the success rate ranges from 70% to 100% in patients who suffer amputation presenting adequate conditions to undergo a replantation procedure. There is a lot of data about success in terms of viability, recovery of sensory and motor activity, but there is no appropriate information about the rate of patient satisfaction and return to labor activities.
Kleinert et al.\(^5\) analyzed 245 patients submitted to replantation procedures and found a successful rate of 70\% concerning viability, and reaching 90\% when only replantations of upper limbs were considered. They also consider that the functional analysis is of extreme importance and it can be based on discrimination and tactile sensitivity, seizing strength, range of motion, presence of cold intolerance and return to work activity.

More recently, Waikakul et al.\(^22\) published a large series of replantations and revascularizations of fingers (552 patients) and reported they found a successful rate of 92\% (946 fingers reconstructed). They emphasize that the type of injury is important to obtain good immediate and late results. Other factors considered relevant by the authors were smoking, prolonged ischemia and injuries in zone II of the hand. The authors do not report a clear distinction concerning the success in terms of survival and the functional results obtained concerning patient satisfaction and use of the operated limb in work activities.

Chow et al.\(^9\) studied the results obtained in 6 cases of forearm replantations and report a 100\% survival rate. They emphasize that the functional result is related to the quality of nerve regeneration and rehabilitation performed. The authors reported they obtained poor results due to the inappropriate return of sensory and motor functions in some clinical cases. They did not analyze the aspect related to return to work activities or the rate of patient satisfaction. The two patients who were dissatisfied with replantation surgery in our series also presented signs of poor nerve regeneration with poor return of sensory and motor functions after replantations in amputations of the proximal humerus.

We noticed better results in replantations of traumatic amputations at more distal levels (wrist and fingers). Tamai\(^20\) also found a high level of survival (89\%) and satisfaction with the result of finger replantation. This author reported that no patient requested reamputation due to functional problems or pain.

Nylander et al.\(^11\) reported the incidence of traumatic amputations in Sweden is 14 cases per one million people (110 cases per year) and replantation would be technically possible in approximately 70\% of cases. Although we do not have reliable statistical data, we could state that the situation is much more serious in terms of incidence and treatment opportunities.

Jones et al.\(^12\) compared groups of patients undergoing amputation and replantation of fingers with functional tests. They concluded that thumb amputation and amputation of multiple fingers, whenever possible, should be treated with replantations.

On the other hand, the functional analysis of patients undergoing replantations of a single finger did not reveal any advantages compared with amputations in most patients. Such data reinforce the importance to analyze the surgical indication for each patient and to provide the opportunity to perform reconstructive surgery in all patients who may benefit from this procedure.

Additionally, our society presents very peculiar behavioral features which are related to our socioeconomic and educational development as well as with the National Institute of Social Security (INSS). Disabled patients are stimulated to retire on invalidity benefits and to start a labor activity in the informal economy. Therefore, the analysis of the questionnaire may determine the impact that successful replantations may cause in our society.

Among the patients studied, 85.5\% were able to return to a productive activity using the reconstructed upper limb. Two patients presented severe functional disability related to loss of mobility and sensitivity and were unable to use the operated limb in a work activity. Seven patients – although not performing any work activities – were able to use the replanted upper limb in routine daily activities. The age range of patients not returning to work is higher and similar findings were reported by Russel et al.\(^13\), who noticed a worse functional adaptation in older patients.

As to patient’s satisfaction, 96.8\% of patients were satisfied with the surgery. We notice that only two patients were dissatisfied with the results obtained. Out of nine patients unable to use the upper limb in their work activities, seven were satisfied with the surgery. This shows that the replanted limb, even if not totally functional, may bring satisfaction to patients. Maybe the esthetical aspect of reconstruction, the emotional bond to the amputated extremity, preservation of the body features and other psychological aspects may explain these data.

**CONCLUSIONS**

We believe that this critical analysis of results of replantations in the upper limb may bring subsidies to implement the creation of new reference centers and to warn the scientific community about the importance of this theme. The data analysis of these findings during a mean period of 84 months reinforces the concept that replantations are procedures related to a high level of patient satisfaction and promote a high level of return to productive activities. It is our responsibility to try to offer complex reconstructive surgery such as replantations to all patients in our society.
REFERENCES

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