



Replantation and revascularization of the upper extremity: clinical experience of a microsurgical department in Portugal

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Abstract

Background Since the pioneering works of Malt and Komatsu and Tamai in the 1960s, thousands of replantations and revascularizations of the upper extremity have been performed worldwide. The advent of microsurgery allowed surgeons to replant or revascularize essentially any amputated part. However, the mechanism of injury or patient comorbidities are important factors that can affect the outcomes.

Methods Patients submitted to upper extremity replantation or revascularization between 2014 and June 2018 were retrospectively analyzed. Demographic features, type of accident, mechanism of injury, amputation level, and success rate were examined.

Results Over the 4.5-year period, 45 replantations and 20 revascularizations were performed. The vast majority of patients were male. The mean age was 45.7 years old in the replantation group and 49.2 years old in the revascularization group. In both groups, the crush/avulsion injury was the most common mechanism. The overall success rate was 57.8% in replantation and 75% in revascularization. The failure in the replantation group was mainly due to arterial insufficiency.

Conclusions The success of revascularization is higher than replantation; however, the mechanism of injury seems to be a critical determinant of the outcome.

Level of Evidence: Level IV, therapeutic study.

Keywords Upper extremity · Replantation · Revascularization · Microsurgery

Introduction

The experimental replantation of amputated parts in animal models dates back to the beginning of the twentieth century; however, it was not until the 1960s that clinical replantation occurred in humans. In May 1962, Malt and McKhann performed the first successful replantation of an arm on 12-year-old boy victim of a train accident, at the Massachusetts General Hospital in Boston [1]. In 1968, in Japan, Komatsu and Tamai performed the first successful digit replantation using microvascular anastomoses [2]. Since then, with the

development of increasingly refined microsurgical instruments and techniques, allied to magnification devices, thousands of replantations and revascularizations are performed worldwide.

Replantation can be defined as the reattachment of a completely amputated part by restoring arterial and venous flow and reconstruction of nerve and musculoskeletal structures. However, amputation can be incomplete and associated with distal devascularization, and in this case, the goal is to restore extremity vascularization through microvascular techniques. The distinction between replantation and revascularization is critical, because viability rates are generally higher in revascularizations, since venous drainage tends to be preserved [3].

The success of a replantation depends on several factors such as age, level and type of injury, ischemic time, expected functional outcome, and comorbidities of the patient. Distinguishing between macro- and microreplantation (amputations proximal or distal to the wrist, respectively) is an

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important factor to be considered. In amputations proximal to the wrist, time is critical since ischemic muscles will irreversibly deteriorate in a few hours. Traumatic rhabdomyolysis due to muscle reperfusion injury, a condition known as crush syndrome, can lead to cardiovascular instability, renal failure, and, ultimately, to death.

The aim of this study is to report the success rate of replantation and revascularization surgery at our center and to point out factors that may affect the final outcomes.

Material and methods

A retrospective analysis of upper extremity replantation and revascularization performed between January 2014 and June 2018 was conducted. The only contraindications to surgery were the presence of major illness or concomitant injury that threatened the patient's life, multiple level amputations, and gross contamination. In all other cases, the replantation or revascularization of the extremity was attempted, after obtaining the patients' informed consent.

In our department, in the immediate postoperative period, patients are admitted to an intensive/intermediate care unit for pain and hemodynamic control, and surveillance of the extremity. Unless contraindicated, venous thrombosis prophylaxis with low molecular weight heparin, acetylsalicylic acid, and antibiotics was routinely administered.

Demographic characteristics of the patients including age, sex, and injured side were collected. The type of accident (work or home related), mechanism of injury (guillotine, crush/avulsion), number of digits injured, type of amputation (complete or incomplete), and success of the operation were also analyzed.

Results

Between January 2014 and June 2018, a total of 45 upper extremity replantations were performed in 28 patients. The mean age was 45.7 years old, ranging from

2 to 81 years. The majority of patients were male (22 cases). The majority of cases were work related (53.3%), the remainder being home-related accidents. Regarding the mechanism of injury, guillotine type represented 35.6% of the cases and crush/avulsion was the cause in 64.4%. The middle and index finger were the most commonly replanted digits, with 11 and 10 cases, respectively. The thumb was replanted in six patients (Figs. 1 and 2). The little finger was the least commonly replanted digit, representing five cases. Seven patients underwent multiple digit replantation. As for major amputation, two arms, one forearm, and three hands were replanted. Globally, the survival rate was 57.8%; however, in the guillotine group, the survival rate was 75.5%, while in the crush/avulsion group, it was 48.3% ($p > 0.05$). Analyzing major and minor amputations separately, all hands and the forearm were successfully replanted (Figs. 3 and 4), but the two arms replanted did not survive (in one case, the patient died 4 days after surgery due to a respiratory infection). Regarding digits, the success rate was 50.0% for the thumb, 60.0% for the index finger, 63.6% for the middle finger, 57.1% for the ring finger, and 40.0% for the little finger.

The cause of replantation failure was arterial insufficiency in two thirds of the cases. In two patients (one thumb and one middle finger in a patient with multiple finger amputation), acute ischemia was detected in the immediate postoperative time and successful revision anastomosis was performed. In the other cases, arterial hypoperfusion led to progressive necrosis. In approximately half the digits with venous congestion, the extremity was successfully salvaged with conservative measures, such as suture release, scarification, and/or topic heparin.

In the same period of time, 18 patients were submitted to upper extremity revascularization after partial amputation. Only 3 patients were female. The mean age at the time of injury was 49.2 years old; the younger patient was 20 and the eldest was 80 years old. Twenty segments were revascularized; the most commonly revascularized segment was the ring finger (six cases) (Fig. 5); four index fingers were revascularized, as well as three thumbs, three middle fingers, one little finger, and



Fig. 1 a–c 56-year-old man with a guillotine-type amputation of the right thumb. Pre-operative findings

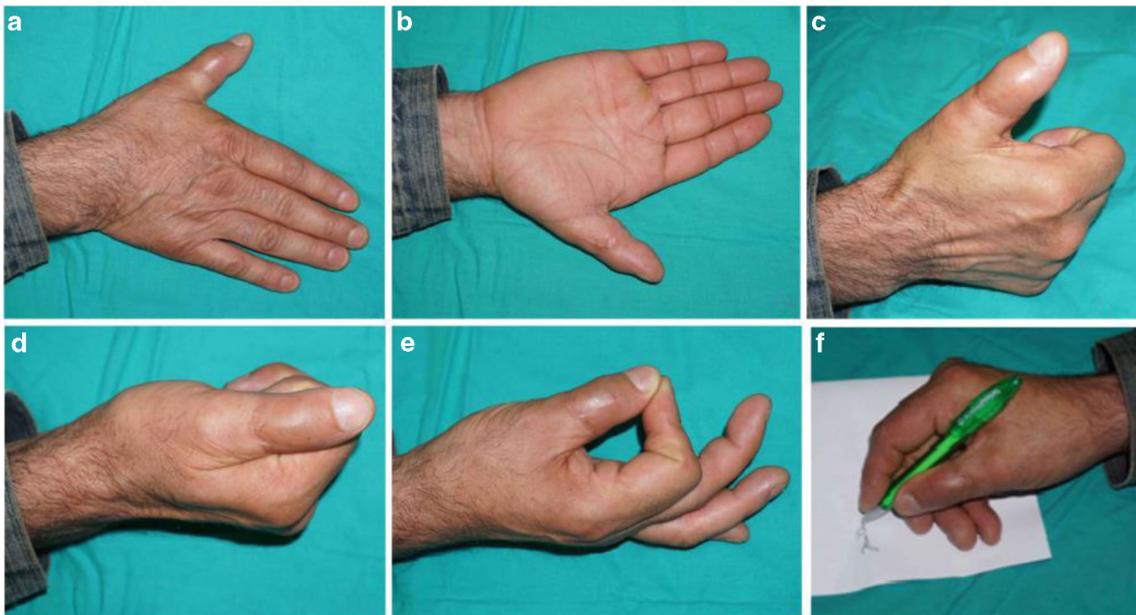


Fig. 2 a–f Twelve months after thumb replantation

three hands. Half of the devascularizations were due to work-related accidents; one case was caused by a traffic accident, and the remainder were home related. Only four cases were guillotine-type injuries.

The survival rate of revascularizations was 75%; in the guillotine cases, all the segments survived (100% survival rate), while in the crush/avulsion group, the success rate was of 68.8% ($p > 0.05$). The three hands were successfully revascularized, as well as 70.5% of the digits.

The survival rate was not statistically different between the replantation and revascularization groups ($p > 0.05$).

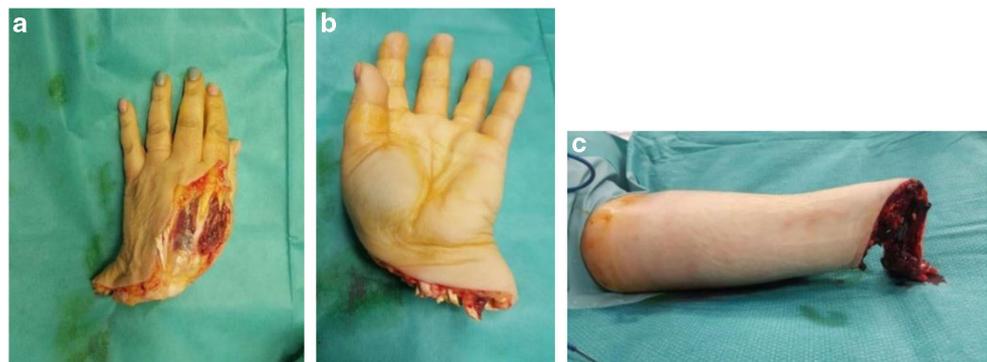
Discussion

The indications for replantation are well established in the literature: multiple finger amputations, single finger amputation distal to the insertion of the flexor digitorum superficialis

tendon, thumb amputation, hand amputation (distal wrist), hand amputation through the palm, and amputation of any part in children [4, 5]. The only absolute contraindication to replantation or revascularization is the presence of a concomitant lesion or disease that threatens the patient's life. All other contraindications, such as single digits proximal to the insertion of the flexor digitorum superficialis tendon, severely crushed or avulsed parts, prolonged warm ischemia time, severe atherosclerotic disease, and multilevel amputations, are considered relative. Indeed, these challenging cases classically considered as contraindications can be successfully performed, as stated by Cavadas [6] or Casal et al. [7]. The commitment of the patient with treatment and postoperative rehabilitation is another important factor that should be considered before surgery.

The success rate of replantation varies in the literature, with rates between 49 and 71% in reports from Western countries [8–10], and rates > 90% in some Asian studies [11, 12]. The

Fig. 3 a–c Left hand amputation in a 40-year-old woman with an industrial machine. Pre-operative findings



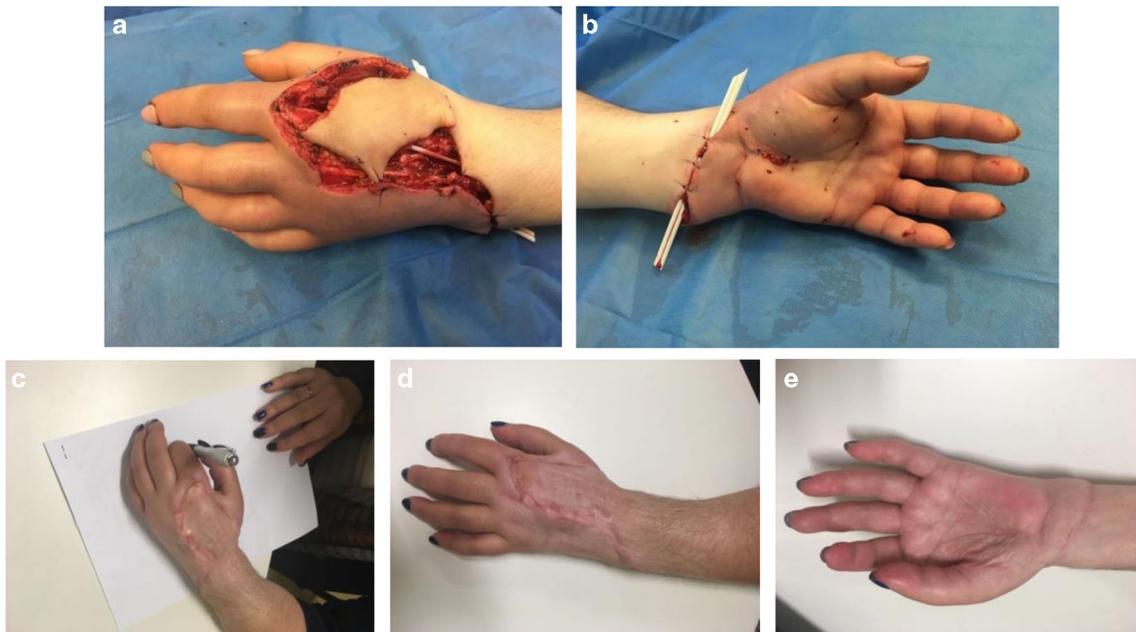


Fig. 4 Postoperative results—day 1 after replantation **a–b**; 12 months after surgery **c–e**

mechanism of injury is a critical determinant to success, with higher rates of survival in guillotine-type accidents [4, 13]. The success rate of revascularization is higher in partial amputations because the venous outflow tends to be preserved [3]. In our unit, the survival rate in replantation is 57.8%, a percentage similar to that reported by other authors. The success rate in revascularization is higher (75%). Although the success rate is higher in guillotine-type amputations than in crush/avulsion injuries, the difference was not statistically significant. The small number of cases probably contributed to this finding.

Although classically the ischemia time does have a role on replantation survival, some recent studies show no differences in survival rates below or above 12 h of cold ischemia for digit replantation [13]; indeed, Wei et al. reported success after very long ischemia times in digits (up to 94 h) [14]. Recently, Cavadas et al. [15] performed a retrospective study of digital replantation comparing the survival rate between digits immediately replanted (immediate replantation group) and those who were replanted the morning after trauma (delayed replantation group). Patients admitted to the hospital after 6 pm

Fig. 5 Ring finger devascularization. Pre-operative findings (**a**); finger after revascularization (**b**). Twelve months after surgery (**c–d**)



were replanted the following morning at 8 am; the procedure was immediately performed in digits with extended previous ischemia times (> 12 h of cold ischemia or > 6 h of warm ischemia), in cases with gross contamination or digital amputations associated with more proximal crushing injuries. The authors found no difference between the immediate and delayed replantation groups, with survival rates above 90%. The results obtained by several authors seem to indicate that, in well-selected cases, micro-replantation can be successfully performed with long cold ischemia times, without jeopardizing the final outcomes.

The correct packaging of the amputated segment is of paramount importance. The amputated part should be transported wrapped in a saline-soaked gauze, placed in a plastic bag, and placed on top of ice.

Two points that must be highlighted in our data are the absence of information regarding transportation of the amputated parts to our microsurgery center and the fact that we were not able to clearly define the ischemia time of the amputated segments.

In a recent past, Costa et al. applied the concept of “flow-through free flap” in replantation and revascularization of the extremities [16, 17]. Indeed, in an upper extremity trauma with a severe crush/degloving injury and devascularization, the concept of one-stage coverage and revascularization by a flow-through free flap is an attractive solution.

We do recognize that the present study has some limitations. It is a retrospective study, and the data regarding some important variables is missing, for instance data on ischemia time. Besides, our replantation surgeries were performed by several different surgeons, which can affect our final results. Nevertheless, and to the best of our knowledge, this is the first report of upper extremity replantation experience in a Portuguese center.

Conclusion

Replantation and revascularization are technically demanding procedures that require long microsurgery training and an experienced team. Our department has an “on-call” team available 24 h a day for extremity replantation and revascularization. The survival rate in our microsurgery department seems to be similar to other Western units. In our series, the mechanism of injury was the only variable affecting the final outcome. A more accurate record of the patients’ features, the ischemia time, and location and type of the accident, added to a larger series, will lead to more precise conclusions.

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Compliance with ethical standards

Conflict of interest Tiago Guedes, Marta Azevedo, João Morais, Carolina Andresen, Gustavo Coelho, Horácio Zenha, and Horácio Costa declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this kind of retrospective study, formal consent is not required.

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