

TRANSMETACARPAL REPLANTATION. ELEVEN YEARS LATER

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Abstract— A case in a series of nine transmetacarpal replantations was presented at the combined meeting of the 7th European congress on Prevention of Hand Traumas and the 7th congress of the Bulgarian Society for Surgery of the Hand, 19-21 October 2023, Plovdiv, Bulgaria.

A male patient aged 42, a heavy truck driver, was an ideal candidate for replantation. In February 2012 he sustained transmetacarpal amputation by circular saw through the proximal third of the left hand, with local crush of the tissues. During replantation enormous tissue edema appeared, caused by long ischemia time with cryopreservation of the amputated part for three hours. Restoration of the common digital nerves was postponed and performed 4 months later (Millesi procedure).

Eleven years later the following outcome is registered. TAM: 110 (good), ab-adduction of 2nd and 4th fingers is restored in limited range. The effect is attributed to reinnervation of some spared interosseous muscles by the motor branch of the ulnar nerve, restored during the autoplasmic of the common digital nerves. The lateral pinch between the thumb and second finger is useful.

The skin sensitivity is examined by Weber static two-point discrimination test (2pdt): 12 mm for 2nd and 3rd fingers, 15 mm for the 4th finger and one point for the pulps of the 5th finger and the thumb; 2pdt, carried out on the palm, in the base of the fingers, is 10 mm.

The gained useful function of the hand is 50%. Original working ability is restored, but it is forbidden for the patient to work as a professional driver. He can drive his own car.

In transmetacarpal replantations with level through the proximal part of the palm some interosseous muscles are preserved, and repair of the motor branch of the ulnar nerve is with favorable prognosis regarding functional recovery.

Keywords— replantation, transmetacarpal, results

1. Introduction

The first successful hand replantation in Bulgaria was performed by B. Popova et al. in the University Hospital “Tsaritsa Yoanna-ISUL” in Sofia, on May 9, 1987. Part of the right hand of a 23-year-old male, amputated through the distal palmar crease, was

successfully replanted. The mechanism of trauma was a guillotine type. The patient currently owns a restaurant. He can write and use the replanted hand. He is content with the treatment and extremely satisfied with the result.¹

Candidates for replantation and revascularization for survival from the whole country were admitted to the Clinic of Orthopedics and Traumatology of University Hospital “Tsaritsa Yoanna-ISUL”, in Sofia by the middle of 2015. The hospital fulfilled functions of a replantation center in Bulgaria. Young surgeons who operated at the Clinic of Orthopedics and Traumatology worked on a voluntary basis, free of charge, whenever a replantation team had to be formed.

The transmetacarpal replantation has a good prognosis for survival, function, and aesthetics of the operated hand^{3,4,5,6,8}. The arteries at this level are bigger than the digital ones, which are about or less than 1 mm. The dorsal veins are well differentiated. The repair of the common digital nerves does not take a lot of time. The tendons of flexor and extensor muscles are transected in favorable zones. The prognosis for bone healing is good. The interruption of the intrinsic muscles is considered irreparable and that has an unfavorable influence on the functional outcome, weak or absent pick and grip strength, in combination with intrinsic contracture^{3,5,6,19}.

2. Material and method

For the period 1987-2015, nine transmetacarpal replantations were performed at the Clinic of Orthopedics and Traumatology at the University Hospital “Tsaritsa Yoanna-ISUL” in Sofia, Bulgaria. One of these cases, of a patient operated 11 years ago, was presented at the combined meeting - the Seventh European Congress for Prevention of Hand Traumas, and the Seventh Congress of Bulgarian Society for Surgery of the Hand (BSSH), in Plovdiv, October 19-21, 2023.

On February 26, 2012 a 42-year-old heavy truck driver sustained an amputation through the palm of the left hand caused by a circular saw. The mechanism of trauma was with a zone of local crush of the tissues. The amputated part was monolithic and included the four ulnar fingers and thumb, with distal two-thirds of the palm, and two-thirds of the thenar eminence. (fig. 1). The contamination by wooden particles was moderate. The importance of the amputated part for the hand was enormous.



Fig.1 Initial state

The patient was transported to the Hospital for replantation 5-6 hours after the accident. During transport the amputated part was properly preserved by cooling. The intake of food and water was timely stopped. The bleeding from the proximal wound was managed by a compression dressing and holding the limb in elevation. The Esmarch bandage, placed on the brachium, was not used during transportation.

The general condition of the patient was good at admission. He did not report any comorbidities (concomitant and past diseases), nor harmful habits as smoking, alcohol consumption etc. The patient's tetanus status was updated at admission, too.

Based on data from the health status of the patient (medical history) and local status, a decision was made that he was an ideal candidate for replantation. The admitting doctor informed the patient and his relatives about the duration of the forthcoming operation, its expected outcome, the possible complications in the early postoperative period, as well as the expected good outcome at the end of treatment.

The case was documented in the operating room.

The replantation was performed by a single surgical team. On a separate small table, under magnification, débridement of the amputated part and removal of the foreign particles of wooden material were performed. The neuro-vascular and tendinous structures in the amputated part were tagged by fine sutures for neuro-vascular bundles and core sutures for flexor tendons, as well as the corresponding in the proximal wound, after the patient had been introduced in general anesthesia. The fractured surfaces of the metacarpal bones were aligned and shortening with several millimeters was performed at the expense of the distal fragment. The osteosynthesis was performed by K-wires, placed intramedullary and transfixing the interphalangeal joint of the thumb. Extensor tendons and the tendon of the long abductor muscle of the thumb were repaired by modified Kessler sutures. The superficial arterial arch was repaired by end-to-end anastomosis. Excessive bleeding, which followed the arterial blood flow inclusion, was left for a short time under control but without intervention so that the toxic products accumulated in the replanted tissues during ischemia were partially removed. Three dorsal veins, which bled profusely, were repaired. The deep flexor tendons of the fingers and the long flexor of the thumb were coapted in an established blood flow. The ischemia time, including three hours with cryopreservation during the transport, exceeded ten hours. The continuous warm ischemia and the tissue trauma by the accumulated superoxide radicals (oxygen free radicals) intervening with reperfusion caused significant soft-tissue edema. The repair of the common digital nerves was postponed for a secondary procedure.

The skin sutures were not tightened up. The dressing contained an abundant amount of cotton. A volar splint maintained the wrist in neutral position.

In the postoperative period the patient received antibiotic prophylaxis, analgetic, sedative (anxiety causes vasoconstriction) and saline solution infusions (saline solution and serum glucose solution, altogether 1.5l/24h)^{9,10}. The microcirculation of the replanted part was observed by the medical staff in the ward for color (pink), temperature of the fingers (warm), turgor of the pulps and capillary refill test (blood supply beneath the nail bed). Nevertheless, the patient is not a smoker, but he was informed that smoking and coffee drinks were forbidden for at least a month after the replantation. The

antithrombotic prophylaxis included Aspirin tb. 325mg/24h and Antistenocardin (Dipyridamole) 25 mg, 3x2 tb, every 24 hours followed by 3x1 tablet every 24 hours for one week after hospital discharge; Aspirin was discontinued one month after discharge. At the time of discharge, the edema of the replanted part persisted, although the limb was held in an elevated position, on pillows (Fig. 2).

Four months after replantation repair of the common digital nerves by auto grafts according to Millesi was performed.

3. Results

“Function is the only real measure of success”, Morrison W.A. et al. 1977¹.

Eleven years after replantation the following result is documented:

The distal interphalangeal joints of the second to fifth finger are in flexion of 10 degrees. The thumb is with flexion contracture of 45 degrees in the interphalangeal joint. There are no signs of intrinsic contracture. (fig.3).

The active motion (flexion-extension arc) of fingers is recovered in a useful range.

TAM:110 (good); TAM=AROM (Active Range of Motion) of MCP (80) + PIP (50) +DIP (0) minus any extension deficit (20). / 13, 21 / (fig.4).

The opposition of the thumb is absent. However, the lateral pinch between the thumb and radial surface of the second finger is recovered and useful. (fig.5)

The grip (prehension) is recovered. The patient can lift and hold a load of at least 1.5 kg with the operated hand. (fig. 6)



Fig.2 Condition at the time of discharge. The edema persists.



Fig.3 Eleven years after replantation, general view of the hand.



Fig.4 Range of motion, flexion-extension of second to fifth fingers



Fig.5 Lateral pinch between the thumb and second finger



Fig.6 Grip

There is recovery of abduction-adduction of the second to fourth fingers, even though with limited range. (fig.7)



Fig.7 Partial recovery of interosseous muscles function

The sensitivity of the replanted part is examined by Weber Static Two-Point Discrimination test (2pdt) by means of a special device (Disc-Criminator). (fig. 8) The following data are documented: 12 mm for the digital pulps of the second and third finger, 15 mm for the pulp of fourth finger, more than 15 mm, one point for the pulp of fifth finger and the pulp of thumb (protective sensation). The two-point discrimination test to the volar surface of the palm, at the base of the fingers, is 10 mm.



Fig.8 Examination of the static two-point discrimination test (2pdt).

Protective sensation is present, but the reaction to hot and cold is delayed with several seconds compared to the healthy hand (based on patient-reported data).

Cold intolerance has decreased with time. Eleven years after replantation, the patient is used to the state and has moderate numbness and pain in the fingers of the left hand in cold weather without gloves or environment such as cold water (on patient's reported data).

Working ability. The patient was a heavy truck driver and according to him, he could do this job again. However, The Medical disability commission has forbidden him to work as a professional driver. Yet he can drive and use his personal car. Hand function is of useful value (fig. 9).



Fig.9 Useful function of the replanted hand

The aesthetic appearance of the replanted left hand is very good. (fig.10)



Fig.10 Aesthetic appearance of the replanted left hand compared to the healthy one

Patient satisfaction with the replantation remains high.

The obtained functional result in the case cited here is classified as **good to excellent**: 50% normal function, sensitivity 10-15mm, recovered grip strength (yes) and recovered ability for original work (yes), (according to Chen's et al. criteria for assessment of the function after extremity replantation)^{12,13}.

4. Discussion

Replantation surgery is a unique surgery procedure³. Repair of all tissue structures during the replantation is the rule we always strive to keep and follow⁴. In this case, the repair of the peripheral nerves is postponed for a secondary procedure because abnormal soft-tissue edema appeared during the second phase of replantation. Other additional operations such as tenolysis, arthrolysis, bone reconstruction for nonunion or malunion^{5,7,29} have not been performed.

The reason for excessive edema of the soft tissues was the long ischemia time, more than ten hours, with only three hours cryopreservation in the transport.

During prolonged ischemia and hypoxia, the Adenosine Triphosphate (ATP) breaks into hypoxanthine (N containing substance) and xanthine oxidase by the action of a protease. When reperfusion occurs, the molecular oxygen permits conversion of the hypoxanthine into xanthine and superoxide radicals (oxygen free radicals). The superoxide radicals can react with water to produce hydrogen peroxide so that with other supplemental oxygen radicals, to form highly reactive hydroxyl radicals (OH). In normal metabolism the superoxide dismutase (SOD) is in sufficient quantities to eliminate these free radicals, but in a period of long ischemia the system is overloaded by excess of free radicals which are extremely aggressive, harmful and toxic and **edema of the vascular endothelial and parenchymatous cells occurs**; stenosis of the capillary lu-

men and disseminated intravascular thrombosis appears, a loss of the physiological venous entity or the capillary wall in the end stage is the essence of the no-reflow phenomenon i.e. with the presence of perfect microvascular anastomoses the tissues remain with no perfusion. This phenomenon should be prevented (cryopreservation of the amputated part with cooling to +4°C and shortening of the critical ischemia time) than treated. Fibrinolytic substances such as urokinase and streptokinase are ineffective towards intravascular fibrinolysis in thrombosis of the small vessels with internal diameter of 0,8-1,5 mm approved experimentally¹⁴.

Eleven years later, abduction-adduction of the second to fourth fingers is restored although with limited range. Intrinsic contracture is not present. Therefore, the motor branch of the ulnar nerve has been repaired concomitantly with the common digital nerves and reinnervation of some spared interosseous muscles (amputation is through the proximal 1/3 of the palm) is achieved. The lumbricals, as part of intrinsic muscles, have dual innervation, the first two by median (contribute pinch) and the second two by ulnar nerve (contribute grasp). Lumbrical muscles have a weak motor function which is only 1/10 of the interosseous but they support interosseous in their function¹⁶. The lumbricals are irreparable in replantation^{3,5,6,7,19}. Therefore, reinnervation of the spared interosseous muscles by repaired motor branch of ulnar nerve is very important and should be performed in selected cases with level of replantation in the proximal 1/3 of the palm.

The recovery of sensory function is assessed by the static Weber two-point discrimination test (2pdt) which is useful after nerve laceration^{17,18}. The test is applied routinely in examination of sensory function after replantation^{3,5,6,7,8,19,20,21}. The original Static Weber (2pdt) does not include examination of sensitivity on the volar palm, but it has been accomplished here for complexity of the investigation. The assessment of the ranges of recovery is according to the normative scale established by the American Society for Surgery of the Hand (ASSH): Normal: 0 to 5 mm., Fair: 6 to 10 mm, Poor: 11 to 15mm, Protective: one point perceived and Anesthetic: no points perceived¹⁷. In general, the average values for the static 2pdt in cases with transmetacarpal or hand replantation vary between 8-12 mm^{19,20,21} but values of 15 mm and more also occur^{5,7,22}. According to the normative scale of recovered sensory function¹⁷ the sensitivity in this case is classified as fair to poor (10-15mm: 10 mm for the volar skin of the palm, 12 mm for the second and third finger, 15 mm for the fourth fingers and one point perceived for the fifth finger and pulp of the thumb), but one must bear in mind that the nerve repair has been performed as a secondary procedure, acc.to Millesi, four months after replantation. The static 2pdt does not always correlate with function²³, and “function” cannot be measured solely by physiology and ability, but it must also embrace the patient’s very personal perception of a successful outcome³.

The K-wire fixation placed in an axial configuration, intramedullary, is quick, atraumatic, technically easier and ensuring sufficient stability so that early passive motions are not critical⁸. It is recommended as a method of first choice in transmetacarpal replantation^{7,8,21,29}. Stable osteosynthesis by plates and screws, or intraosseous metal wire in combination with K-wires (Lister procedure) or by two intraosseous wires placed perpendicularly to each other (90-90 wire procedure) are alternative options^{24,25,26}. However, the stable osteosynthesis by plates and screws is more traumatic for the soft

tissues than longitudinally placed K-wires, while intraosseous cerclages are more time-consuming and not stable enough for metacarpal bones. On the other hand, the Lister procedure and 90-90 wire procedure recommended in digital replantation are considered to have low non-union rates^{2,8,25,26}.

The order of tissue repair during the cited replantation – osteosynthesis, extensor tendons, superficial arterial arch, dorsal veins, flexor tendons and the postponed nerve repair – do not correspond completely to the classical one⁴. As to which micro-anastomosis comes first, arterial or venous, we prefer arterial repair first to locate veins by back bleeding, while others prefer the opposite, venous repair first⁸. Changes to the order of repair of the various tissue structures are allowed, according to the specific patient and surgeon's preferences^{4,8}.

There is no uniform antithrombotic protocol for replantation in the hand area^{3,27,28,29}. Opinions vary from total restraint from thromboprophylaxis to including Heparin as anticoagulant (appropriate type, Standard or LMW, dosage and timing) or drugs with antiplatelet effect (antiaggregant) such as Aspirin. The use of systemic Heparin for thromboprophylaxis in transmetacarpal replantation is not recommended. Instead, antiplatelets are widely recommended such as low-dosage Aspirin in combination with Dextran^{7,8}. We do not administer Dextran because of its side effects. We used Aspirin 325 mg tb. once daily, combined with Antistenocardin (Dipyridamole) tb 25 mg, 3x2/24h. Antistenocardin (Dipyridamole) is an Aspirin analog which also has anti-prostaglandin and possible vasodilatory effects¹⁴. In addition to the antithrombotic prophylaxis, the patient must be well hydrated.

The indications and contraindications for replantation are specified, but they are not considered absolute^{3,4,8,30,31}. Each case is subjected to a three-component analysis: **trauma** (exact time, mechanism of trauma, level of amputation and concomitant injuries, if present), **amputated part** (general view, state, significance for the hand function, contamination) and **the patient** himself with his/her specificities (in the first place age; children have better recovery prognosis than elders, health and psychical status at the moment, comorbidities now and in the past, harmful habits, profession and personal desires)²⁹. The ischemia time is of exceptional significance (ischemia of more than 10 hours impacts negatively the outcome.)⁸. The storage of the amputated part – cryopreservation to about +4°C or without cooling (warm ischemia) - is also of utmost importance. For amputated parts which contain musculature the time of ischemia is a critical parameter (six hours without cooling and twelve hours with cooling)^{4,8}. For a single finger the limitations are not so strict^{4,8,29}. The requirement for a transmetacarpal replantation, as well as for all others, is storage of the amputated part by cooling, which extends the limits of the ischemia time. The exact instructions for preparation of the amputated part and the patient for transport are described in the transport protocol, The Emergency Information Protocol was borrowed from the Hand Care Center in Louisville, KY, the USA, translated into Bulgarian, and was sent multiple times to the hospitals in the country 20 years ago³¹.

The replantation does not end in the operating room. The surgery is only one component of the treatment⁷. The survival of the replanted part depends also on the work of the team in the department – the competent, knowledgeable doctors and nurses who observe microcirculation by clinical signs and tests and by probes. Some probes are

rather complex³². Several instrumental methods have been tested and Laser Doppler flowmetry shows the most promising results among them³⁸. The probe for surface thermometry is an easy and inexpensive postoperative monitor of microcirculation³⁸. The probe is attached superficially to the pulp of the replanted finger (or free-tissue transplant). If the local skin temperature (normally 32 degrees) drops below 30 degrees C, poor perfusion of the replanted part is certain. The cause for the compromised circulation must be found and corrected if possible. The probes' registered data precedes clinical data and warns us in time^{36,37}. The following urgent actions must be undertaken in such a situation - change of the dressing, removal of several skin stitches, change in the position of the hand and extremity, sympathetic block and local anesthetic (Bupivacain or Lidocaine solutions) through the axillary catheter (if present), medicinal leeches (we have a very good experience with medicinal leeches and find them useful in critical situations, such as venous congestion or arterial insufficiency), anticoagulatory drug infusion, Heparin, if it has not been already started (optional). The last step is re-exploration of the microvascular anastomoses, but within six hours and not later after the beginning of the complication. The decision for anastomoses' revision is taken cautiously, bearing in mind factors that may affect circulatory embarrassment, like high blood pressure, for example. Not all revised parts survive but anastomoses' re-exploration is a reasonable salvage procedure that increases significantly the survival rate (from 67,6 to 84,2% according to a study on finger replantation)³⁹. It is particularly important to ensure high quality micro-vascular anastomoses to reduce the probability of thrombosis, vasospasm and need of re-exploration. The traditional supervision of less experienced surgeons may be realized by distant cameras (Patency Test High Speed Video Recorder, PTHVR) This decreases the rate of re-exploration surgeries and improves the success rate of microsurgical operations⁴⁰.

Replantation represents the culmination in the field of hand surgery^{8,34,35,41}. The classical principle of hand surgery "preserve length and function" can now be modified to "restore length and function"³⁵. However, it is unfeasible without proper microsurgical technique, adopted previously by stubborn training in the microsurgical laboratory. And this rule is still alive and valid^{15,42}.

A decrease in the number of replantations was reported recently on a global scale and hence a reduction of success rates (survival)^{7,43}. The reasons cited are decrease of work accidents and industrial traumas, problems with funding the surgical procedures, lack of specialists engaged with replantation, caused by the inadequate payment, reimbursement opposed to invested labor and efforts, patients' refusal of replantation, when a single finger has been amputated, juxtaposed with the temporary disability, absence from work and return to previous employment. An increasing number of specialist share the opinion that successful replantation surgery (in the meaning of "survival without restoration of function is not success")⁴⁴ should only be performed in major hospitals or specialized centers, where there are appropriate conditions for its performance and where future microvascular surgeons can prepare for independent work. "The knowledge and skill gained must be shared and taught to younger replantation surgeons allowing for elevation of the entire field"^{3,29,43}.

5. Conclusion

In transmetacarpal replantation with level of amputation through the proximal 1/3 of the palm the motor branch of the ulnar nerve must be repaired, better primarily, together with the common digital nerves. This increases the probability of partial restoration of abduction-adduction of the fingers, and the occurrence of a more powerful pinch and grip function without signs of intrinsic contracture.

Minimizing ischemic time must be of top priority – adequate transport to the relevant hospital, expeditiously preparing the patient for the forthcoming operation and starting replantation as soon as possible with all prerequisites available.

Whenever dealing with a case of transmetacarpal amputation (or of the whole hand), the best solution for the surgeon and patient remains replantation. The recovered working ability justifies the high cost of treatment. A replantation in the hand area must always be our first choice, especially in children, when proper indications are present, in combination with specialized surgical and anesthesia teams and equipment with an operating microscope, microvascular set of instruments, and ultra-fine suture material for microvascular anastomoses.

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