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Reimplantation, transplantation

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The impact of replantation surgery upon reconstruction of the hand has been immense since the first revascularization of a digit performed by Dr. Harold E. Kleinert in 1962, and published in the Kentucky Journal of Medicine in 1963. Malt reported by the media on full replantation of the upper extremity in 1962. Kumatsu and Tamai in 1964 replanted a thumb which was published in 1967, following which surgeons became comfortable with the idea of putting small vessels together, and that spun on the ability to transfer the recently discovered, at that time, the axial pattern flap into free flaps. The history is then wide, and this has influenced every aspect of our lives.

Before replantation, patients had mutilations that left them with both a stigmata of an injury and the inability to use the extremities. Not only in regard to the loss of the digits, but often because the lack of blood supply resulting in ischemic parts that fibrosed and lacked motion.

Replantation was then born around the world, in Japan, Kumatsu and Tamai, in China with Chen Zong Wei, in Australia, Ian Taylor and Bernie O'brien, in United States, Kleinert and Buncke. Initially the surgeons were happy to just making things pink, survival being the rule of the game. Today function is the end result sought.

From up into the arm to the tip of the fingers, refinement of replantation has taken place. Cooperative teams working together to reduce surgery time were formed. The work of the Japanese, Chinese, as well as those in Germany had large numbers of patients with replantation with very acceptable results.

However, amputation occurs at times in both upper extremities, and at times all the extremities. The injury in some cases is of a crushing type rendering the amputated part not replantable to its corresponding stump. In cases of bilateral amputation, ectopic replantation may save function in one extremity. The first documented case of transposition of a hand, or switching of the upper extremities was carried out by Dr. Joseph E. Kutz in Louisville, Kentucky, on a gentleman who sustained bilateral upper extremity amputations. This individual's one side proximal stump would not accept the replantation of the distal part that was in good condition, while the contralateral stump was good condition and the distal part was totally crushed. The transfer of the right hand to the left hand position resulted in the thumb facing down, being placed in the ulnar position, but the patient had sensation and range of motion with the final outcome of the patient not requiring complete dependence on a prosthesis.

Ideally, the goal of replantation is to return the severed part to normality, but the most practical goal is whether or not the replanted part will allow the patient a better functional result than amputation. Over the years the results of replantation have improved with continued advances in medical and surgical techniques, as well as training of specialized surgeons and medical teams in this area. Indications and contraindications have evolved greatly over the past 39 years. Because of the success of replantation and revascularization techniques, the emphasis has shifted from survival of the replanted limb/part, to achieving good function.

Post-operative care is just as vital to the part, as the success of the replantation surgery. The results will be less than acceptable should the patient not follow a close psychological counseling for the patient and families in cases where indicated.

Replantation of an extremity or part of one is now an effective and well-established technique. Mobilization can be started earlier in clean amputations. The physical and mental status of the patient is also important; however, if the patient's overall medical status is good, fewer complications are likely to occur. Depending upon the type of bony stabilization, tendon, nerve and vessel damage and repair with excessive shortening may also delay the onset of mobilization of the involved extremity/part.The level of amputation is also imperative in the orchestration of a rehabilitation program.

Digital motion is of utmost importance, and must be considered in all levels of hand replantation. It is now well known that finger replantations at the proximal phalanx obtain poorer results and range of motion than amputation at the distal interphalangeal joint. In the same way a hand amputation at the wrist level will have a better outcome than a hand amputation through the mid-metacarpal level. Because the latter will involve the intrinsics, leading to claw-hand deformity or the so called intrinsic minus hand.

Because all of the structures, including the skin, tendons, bones, joints, nerves, and vessels, are involved in a complete amputation, rehabilitation is complex. Sometimes it is necessary to favor a certain set of structures over others. How soon the

rehabilitation program can begin depends on the quality of the bone fixation, the condition of the skin and whether excessive shortening of tendons or nerves has occurred. Usually when replantation is performed at the wrist and distal forearm level, a proper rehabilitation program will enable function to reach an acceptable level. Meyer in 1985 analyzed 80 amputations at these levels utilizing the Chen grading system, finding 80% of good or excellent results.

However, the functional outcome of transmetacarpal replantation did not show as much success. Chen et al reported only 59% good and excellent results for 54 transmetacarpal replantations. This figure lies midway between those of their wrist and proximal forearm replantation results. Russell et al reported on seven patients with transmetacarpal replantation. Three of these had no grip strength and the other four had no pinch strength.

These injuries ranged from guillotine cuts, which achieved the best functional results, to local crush, to avulsion, which had the worst overall function. In each of these patients, the intrinsic muscle function was weak or absent, although normal thenar muscle function was retained. Russell reported that a strong patient commitment to postoperative occupational and physical therapy improved functional results.

We developed a treatment protocol for postoperative management of the replanted hand. Once the viability of the replanted limb is guaranteed, the focus of rehabilitation becomes the restoration of normal form and function after injury. We define "normal" function as the ability to perform physical, psychosocial, vocational, and recreational activities as the same level as before the injury occurred. This includes mobilization of the reattached part as soon as possible, within 24-48 hours post-replantation in a clean amputation. This reduces edema and stiffness, as well as prevention of intrinsic minus hand and claw deformities. This occurs because when the intrinsic muscles are injured, the distal portion becomes ischaemic. This causes loss of muscle function, which, in turn, causes an imbalance of the pull between the intrinsic extensors and the lack of intrinsics. In the normal hand, digital flexion begins at the metacarpophalangeal (MP) joint and progresses to the distal interphalangeal (DIP) and then the proximal interphalangeal (PIP) joints. When claw hand deformity occurs, the MP joint remains extended during the initial phase of the flexion due to the imbalance in the pull of the extensor tendon, while the DIP joint and then the PIP joint move into flexion. The distal transverse arch becomes completely flattened, which, in turn, renders the thumb useless except for the lateral grasp. The rolling flexion of the intrinsic-minus hand may occur due to scar tissue that attaches the intrinsic tendons to their canals in a lengthened position. This condition results in the "flat hand" of the patients with transmetacarpal replantation reported by Russell et al; the hand's ability to grasp and manipulate objects is severely reduced by this rolling flexion.

This problem may occur not only in replantations in which the intrinsic muscles are directly injured. In 1984, Russell et al reported poor intrinsic muscle function after injury at all levels if proximal nerve division or stretching had occurred, and whether or not the intrinsic muscles had been injured directly.

During surgery it is of paramount importance to perform three procedures that will enhance success of the early mobilization/bracing program. 1: ligate vessels not used for replantation to prevent hematoma, 2: Reduce amount of devascularized / functionless tissue to reduce the risk of infection or post-op fibrosis, 3: Keep bone fixation bulk to a minimum to avoid interference with early extensor tendon gliding over the dorsum of the hand. We have created a dynamic crane extension outrigger splint that mimics intrinsic function of the hand. This splint differs from others as it reduces the force on the repaired fingers, as much of the force of the rubberbands is dissipated into the crane outrigger and the tower base. This then allows less tendon ruptures, and to date I have had none with this device. Loss of the intrinsic muscles and their role in flexion of the metacarpophalangeal (MP) joints is a disabling condition. It is associated with other conditions besides forearm, wrist and transmetacarpal replantations. For example, loss of the intrinsic muscles is frequently seen in wrist level injuries in which both the median and the ulnar nerve have been cut and the post-operative treatment plan did not use appropriate splinting and therapy. The intrinsic-minus posture is difficult to correct once it becomes a fixed deformity. To prevent such a condition, treatment must be modified in the days and weeks immediately following the initial surgery. Meyer et al mentioned splinting in this early report of transmetacarpal replantation, but subsequent review articles have rarely detailed post-operative splinting protocol, especially regarding the intrinsic minus hand replantation.

At approximately 4-5 weeks post-surgery, and depending upon bony healing, wrist & forearm range of motion is initiated within a hand based anti-claw splint that is fabricated at that point. (Discussion of fabrication and usage is discussed at point in presentation).

From 8 to 12 weeks post-surgery other therapeutic modalities are added depending upon the level of healing and usage gained at that time.

At 12 weeks post-surgery a dynamic wrist extension splint is applied by connecting it to the anti-claw splint. This aids in strengthening of the wrist flexors and extensors by allowing wrist flexion against resistance and assistive active extension. This splint is used three to four times a day for 15 to 30 minutes. It helps strengthen the repaired tendons and muscles by increasing flexor strength and balancing the antagonistic muscle groups. Light weights are used to isolate and strengthen specific muscle groups such as the wrist flexor and extensors. Its use is alternated with the crane outrigger splint. The anti-claw splint is worn alone when exercises are not being performed.

Although most reports of the functional results of replantation at the metacarpal level have been poor, the author has reported good functional results with the early use of the dynamic crane outrigger splint with an MP joint extension block described here.

Promoting early protective active motion and blocking MP joint extension help achieve a hand with an intrinsic-plus posture and coordinated grasping. Although this protocol does not show an improvement over the functional results at the wrist and distal forearm reported by Meyer, its use can help prevent intrinsic-minus deformity, which is a concern in most amputations proximal to the MP joint, according to Russell et al. With this technique, the need for subsequent surgery is reduced. However, tenolysis may be needed in some patients, but it should not be performed until six months post-operative.

The most recent development in replantation is the newly recognized procedure of human extremity transplantation. Although organ transplantation has been widely accepted as an option for patients, there was a split in the medical community in regard to transplantation of an extremity from a donor to a living patient, as it was felt that this was not a life threatening condition and in the past, it was strongly believed that the contraindications and risks were too high to accept for any patient, and transplantation was not deemed an appropriate option. Through the indomitable perseverance of the hand transplantation teams it has been proven that human transplantation is a very viable option for those patients with the loss of an extremity.