Major upper extremity replantations

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Abstract The usual mechanism of a major amputation creates a mutilating injury. Although survival rate is high, the functional results are guarded [1, 2]. The aim of this study is to review our experience with major upper extremity replantations performed between the years 1987–2007 with respect to the type of amputation as proposed by Chuang et al. [3]. 23 upper extremities were replanted in 22 patients (7 arms and 16 proximal forearms and elbows). All but one replanted parts survived. Out of 6 patients with arm replants 4 gained useful extremities and two had poor result after more than 2 years of rehabilitation and 17 additional surgical procedures. Out of 16 replanted forearms, after more than 2 years of rehabilitation period and 50 operations, useful extremity was achieved in 11 and poor result in 5. The main factor influencing functional result was the type of amputation according to Chuang et al. [3].

Keywords Replantation · amputation · mangled upper extremity

Introduction

The usual mechanism of a major amputation of a limb involves crush, avulsion and traction, causing mutilating injuries with disruption of bones, soft tissues, vessels and nerves at different levels. Major limb amputations are potentially life threatening and replantation of a limb at a proximal level is a major surgical endeavor. The success of proximal level replantation depends on the patient's condition, the condition of the amputated part and the stump, the time elapsed since the amputation, and the experience of the surgical team. Although survival rate of proximal level replants is usually high, the functional results are guarded [1, 2], even though they have improved tremendously since the advent of functioning muscle transplantations [4, 5]. The obvious questions arising before attempting proximal level replantation are: Will the end result be better than prosthesis? What can be expected in terms of function in the individual case? What is the expected price to achieve this goal in terms of morbidity? Unfortunately there is no known objective scoring system for these injuries which can reliably predict the functional outcome and make the decisions easier, since no scoring system takes into consideration the possible secondary procedures to improve the function, and the decisions rely heavily on the surgeon's expertise and skill. It is a well documented fact that the MESS score is not applicable to hand injuries since even a bad hand is usually better than the available prosthetic substitute [6]. D. Chuang et al. [3] proposed a classification of amputation types based on the level of disruption of muscles and nerves rather than bone, assuming that the amount of normally innervated muscle in the proximal stump is the main determinant of later function. According to this classification there are 4 types of major amputations:

Type I: avulsion at or close to the musculo-tendinous aponeurosis with the muscle remaining intact and functional.

Type II: avulsion within muscle bellies but distal to neuromuscular junction, with the proximal muscles still

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being innervated. (In this context, the motor nerve refers to the anterior interosseous nerve in the forearm and musculocutaneous nerve in the arm).

Type III: avulsion within the muscles but at or proximal to the neuro-muscular junction, with the entire muscles being denervated and/or destroyed.

Type IV: avulsion through the joint (elbow or shoulder joint disarticulation).

We revised our results with major upper extremity replantations according to this classification.

Patients and methods

Between the years 1987–2007 we replanted 7 arms and 16 forearms and elbows in 22 patients. All but one replanted parts survived. One replanted arm had to be amputated 5 days following replantation due to severe post reperfusion syndrome and infection. There were 21 male patients and 1 female, mean age 25 (range 2–60); 13 patients injured at work, 8 patients injured in traffic accidents one patient was a war casualty; 15 complete and 8 incomplete amputations; in one patient both forearms

were amputated near the elbow joints. The follow-up period was 18 months – 19 years, mean follow-up period was 10 years.

According to the classification proposed by Chuang et al. [3] only type 2 (4 patients) (figure 1) and type 3 (figure 2) (3 patients) amputations were in the above elbow group (Table 1). At the forearm/elbow level 3 forearms were type 1, 4 forearms type 2, 6 forearms type 3 and 3 were type 4 elbow disarticulation-amputation (Table 1).

Our approach to major replantations is ideally a two-stage procedure, although often more than two initial surgical interventions are necessary. The first procedure includes extensive debridement of denervated muscles and necrotic soft tissues, liberal shortening of bone, revascularization and distal fasciotomies. Primary nerve/tendon/muscle repair is performed whenever possible

Fig. 1 (a) 8 years old boy with type 2 amputation above elbow (b) functional result of 8 years old boy 18 months post type 2 injury replantation of arm—excellent result.

Fig. 2 (a) 23 years old patient with type 3 amputation of arm (b) 23 years old patient 2 years following replantation of type 3 amputation of arm—good result.

Table 1. 22 patients according to level of amputation and type of injury

Type of amputation	Arm level (7 patients)	Elbow and forearm level (15 patients, 16 parts)
Type 1	0	3
Type 2	4	4
Type 3	3	6
Type 4	0	3

during the first procedure. A ‘second look’ procedure is performed 48–72 h later. At this stage we try to get the wounds closed either with skin grafts or flaps (either pedicled or free) and sometimes perform the nerve repair including nerve grafts. For arm level replantations we prefer pectoralis major muscle transfer for anterior wound closure and restoration of elbow flexion and latissimus dorsi muscle for posterior wound closure and elbow extension. We do not postpone the nerve repair longer than 2 weeks. Whenever warm ischemia time is longer than 6 h, we refrain from replantation attempt [7, 8]. According to these guidelines, all our patients had at least two primary care operations in the immediate post injury hospitalization period. Most of our patients however, (4 out of 7 patients with arm level amputations, and 10 out of 15 patients with forearm level amputations), needed 3–5 additional debridement procedures before definitive wound closure was performed.

The rehabilitation period ranged between 2–4 years. All the patients required numerous secondary reconstructive procedures. In the 6 patients post arm replantation we performed 17 secondary operations to achieve function, including 4 nerve grafting procedures, 3 bone grafting, 5 tenolysis, one soft tissue free flap, 2 pedicled muscle transfers (pectoralis major) and 2 free functioning gracilis muscle transfers (Table 2).

50 procedures were needed in the forearm/elbow replantation group (Table 3), including 11 nerve grafting, 7 bone grafting, 12 tenolysis, 8 free soft tissue flaps, 3 pedicled muscle transfers (latissimus dorsi), 4 tendon transfer procedures and 5 free functioning muscle (gracilis) transfers. At least 2 additional procedures were needed in type 1 and 2 amputations and at least 4 procedures in type 3 and 4 amputations. Tenolysis was the most frequent procedure, since tendon adhesions was the most difficult problem. It was not performed only in elbow disarticulation (type 4) injuries. Functioning muscle transfers: pedicled (pectoralis major, latissimus dorsi) and free (neurovascular gracilis transfer) were needed in type 3 and 4 amputations only, tendon transfers were performed in type 3 injury only.

Results

The functional results were evaluated according to criteria suggested by Chen [9] taking into consideration sensibility, range of motion, strength and use of the injured extremity in activities of daily living (Table 4). Since ‘occupation’ criterion is not applicable to children, we further grouped the patients as having a useful extremity (excellent and good results) or a not useful one (fair and poor results).

Table 2. Secondary reconstruction procedures performed in arm level replantation patients according to type of injury (6 patients, 17 procedures)

Type of injury	Procedure						Total number of procedures
	Nerve graft/ nerve transfer	Bone graft/ osteotomy	Tenolysis	Free flap cover	Pedicled muscle transfer	Functioning free muscle transfer	
Type 2 (3 patients)	1	2	3	–	–	–	6
Type 3 (3 patients)	3	1	2	1	2	2	11
Total (6 patients)	4	3	5	1	2	2	17

Table 3. Secondary reconstruction procedures performed in elbow/forearm replantation patients according to type of injury (15 patients, 16 forearms; 50 procedures)

Type of injury	Procedure							Total number of procedures
	Nerve graft/ nerve transfer	Bone graft/ osteotomy	Tenolysis	Free flap cover	Pedicled muscle transfer	Tendon transfer	Functioning free muscle transfer	
Type 1 (3 patients)	2	2	3	1	–	–	–	8
Type 2 (4 patients)	2	1	2	2	–	–	–	7
Type 3 (5 patients 6 parts)	4	4	7	4	1	4	5	29
Type 4 (3 patients)	3	–	–	1	2	–	–	6
Total (16 forearms)	11	7	12	8	3	4	5	50

Table 4. Criteria for evaluation of results

Excellent	Back to work; Total ROM ¹ ≥60% normal; Sensibility ≥S2 Strength ≥M4
Good	Some work; Total ROM ≥40% normal; Sensibility ≤S2; Strength ≥ M3, no pain
Fair	Some use in ADL ² , Total ROM ≤30% normal; less than protective sensation – Strength < M3
Poor	Survival without function

¹ROM = Range of motion. ²ADL = Activities of daily living

Table 5. Functional results according to type of injury in 6 arm level replantations

Type of injury	Results				Total number
	Useful extremity (4)		Non-functional extremity (2)		
	Excellent	Good	Fair	Poor	
Type 1	2	1	–	–	3
Type 2	–	1	1	1	3
Total	2	2	1	1	6

Two patients with type 2 above elbow amputations gained better than protective sensation. 1 patient with type 3 injury in the above elbow group and 3 patients with elbow disarticulation gained almost no sensation. The rest of the patients in both groups gained protective sensation. None of the patients suffered from chronic pain in the replanted extremity after 2 years. Only the 2 years old child with above elbow type 2 amputation gained function of the intrinsic muscles.

Out of 6 patients with arm replants 4 gained useful extremities (excellent and good) for activities of daily living (figure 1b), 3 of them with type 2 injuries and 1 with type 3 (figure 2b). The other two patients with type 3 injury had a non functional extremity (a fair and a poor result). (Table 5). None of the patients returned to previous occupation, and the 2 years old baby changed his dominance although his functional result was considered excellent.

In the forearm amputation group 11 patients gained useful extremity (3 excellent and 8 good) and 5 forearms in 4 patients did not achieve any function (fair and poor). (Table 6). The non functional extremity was the end result in 3 patients with type 4 injury and 2 patients with type 3 injury (in one of them one of the forearms of the patient with bilateral injury).

None of the patients with non functional extremity requested amputation.

Discussion

Major upper extremity replantations are relatively rare and their management is difficult. The immediate survival rate is high, but the final functional results are often disappointing. The published case series are small and

there is no scoring system to help with the immediate decisions. The best proposed classification of type of amputation with prognostic significance is that of Chuang and colleagues [3]. Our results support the reliability and importance of this classification. We found that classifying the amputation type based on disruption points of muscles and nerves as proposed by Chuang and colleagues [3], rather than the level of detachment of bone created groups of patients with need for similar secondary surgical procedures and final functional result. In the arm level replantation group only type 2 and 3 injuries were encountered, with almost twice as many secondary procedures performed in the type 3 group. The functioning free muscle transfer as well as pedicled muscle transfer and free soft tissue flap was performed only in the type 3 patients. The 2 patients with the worst final result (non functional extremity) were with type 3 injury. We observed a similar pattern in the forearm level replantation group: the type 3 group of patients needed almost twice as many secondary procedures as compared to the other types. Only patients in type 3 and 4 injury needed functioning muscle transfer procedures – either pedicled or free. The worst final results were in all the patients with type 4 injuries and 2 of the patients with type 3 injuries. All the patients with type 1 and 2 injury achieved useful extremity.

Pedicled muscle transfer was used in 2 arm replantation patients and in 3 forearm and elbow level replantation patients. We used pectoralis major muscle for restoration of elbow flexion and the latissimus dorsi for elbow extension. Some authors [10] prefer using latissimus dorsi for elbow flexion, but we feel that pectoralis major provides better proximal wound cover and leaves latissimus dorsi muscle for possible secondary recon-

Table 6. Functional results according to type of injury in 16 forearm/elbow level replantations

Type of injury	Results				
	Useful extremity (11)		Non-functional extremity (5)		Total
	Excellent	Good	Fair	Poor	
Type 1	2	1	–	–	3
Type 2	1	3	–	–	4
Type 3	–	4	1	1	6
Type 4	–	–	–	3	3
Total number	3	8	2	3	16

struction. The expected rehabilitation period is 2–4 years and at least 2 additional surgical procedures are needed for type 1 or 2 injuries, and more than 4 for type 3 and 4, including usually a functioning muscle transfer. The worst results are to be expected in type 4 injuries.

Other generally accepted factors influencing functional results in hand surgery such as patient's age and motivation might be important, but due to relatively small number of patients in each group we could not prove this in our study.

Conclusions

We found that a factor influencing functional result of a major upper extremity replant is first of all the type and extent of injury as proposed by Chuang and colleagues [3]. The classification of the type of injury suggested by them is predictive in terms of expected morbidity and functional outcome, and therefore is a pertinent and important one.

We feel that a major upper limb replantation is always indicated in a young patient (except shoulder disarticulation) thanks to the advent of free functioning muscle transfers, which have made major upper extremity replantations worthwhile even for type 3 and 4 injuries. The achieved functional result is usually better than prosthesis, and even when the function is limited, patient satisfaction is high.

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