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ORIGINAL ARTICLE

Delayed Procedures in Irreparable Brachial Plexus Injuries

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Abstract

Background: The management of brachial plexus injury represents one of the most complex challenges. Surgical options include neurolysis, neurorrhaphy, repair with nerve graft, and neurotization. Delayed procedure are required to restore and salvage function in patients with late presentations and in a setting of suboptimal results of primary procedures. Appropriate timing is an important factor to be ascertained.

Aims and objectives: The objectives are to establish the time of intervention, to evaluate the practical aspects of planning, operative technique, assessment of outcome in various muscle and tendon transfer procedures, as well as post-operative management and complications. Whenever feasible, the results of different procedures aimed at producing similar movements are also compared.

Materials and Methods: A total of 19 patients underwent 20 delayed procedures between November 2010 and October 2013. All 19 patients included in the study were males. Selection criteria included patients who presented late (>9 months), and cases without spontaneous recovery or ones that showed no improvement after primary surgery.

Observations and Results: Among the procedures**,** muscle transfers included free functional gracilis in 9, modified trapezius in 7 patients and latissimus dorsi transfer in 1 case, 2 Oberlin procedures and 1 tendon transfer were performed. The follow up period ranged between 12- 30 months, with majority of the patients showing M3 improvement.

Conclusion: Delayed procedures are an integral part of brachial plexus reconstruction since only partial recovery can be achieved in a subset of patients, especially with severe lesions. Timely intervention, surgical expertise and dedicated physiotherapy are the keystones for optimal improvement and recovery.

Keywords: Brachial plexus, delayed procedures, trapezius transfer, free functioning gracilis.

Introduction

Brachial plexus is a complex structure in the peripheral nervous system, which innervates the muscles, articulations and tegument of the shoulder girdle and upper limb. Its vulnerability to trauma is predisposed by virtue of its large size, superficial location, and location between two highly mobile structures (neck and upper extremity). Brachial plexus injuries are devastating and are usually associated with high levels of disability and permanent morbidity. Treatment of injuries to the brachial plexus is generally demanding and a challenging domain of surgery for upper extremity. Advances in the reconstruction of complex nerve lesions have paralleled advances in microsurgery in as much as the same technical achievements in optics, sutures and instruments. Significant early advances in the reconstruction of nerve lesions are attributed to Hanno Millesi of Vienna[1], who in 1972 published his results of the use of interfascicular nerve graft techniques in complete injuries of the median and ulnar nerves.

Reconstructive strategies to restore hand function: Prioritization of upper limb reconstructive surgery is a

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matter of debate amongst the surgical fraternity. Each patient presents with an unique injury and pattern of paralysis. The strategy to allocate priority depends initially on restoring elbow flexion, followed by shoulder stability and/or abduction, and finally restoration of hand function. A stable shoulder increases the function of the reinnervated elbow flexors and a functioning elbow increases shoulder use. Some surgeons perform arthrodesis of the glenohumeral joint, thereby allowing valuable donor nerves to be used for more distal functions. Restoring protective hand sensation must be included in the reconstructive plan.

Primary surgical options include neurolysis, neurorrhaphy, repair with nerve graft and neurotization. Final outcome of primary surgery depends on factors like mode, site, type of injury and age of patient. Treatment factors like time since injury to surgical intervention, availability of diagnostic modalities, type of surgical intervention, and pre- and post-operative physiotherapy aids in deciding the final outcome. This influences further management in case of partial recovery or failed cases. When patients present with long denervation time or failure of the primary procedures to achieve desired outcome, decision regarding delayed procedures are contemplated in an effort to restore the lost functions. Appropriate timing of delayed procedures is an important factor that needs to be ascertained.

Delayed procedures are an integral part of brachial plexus reconstruction because only partial recovery can be achieved, especially in severe lesions. The goal for abduction and external rotation of shoulder can be achieved by latissimus dorsi or trapezius transfers. In selected cases however, shoulder arthrodesis gives satisfactory results. In delayed cases, a free muscle transfer (e.g. gracilis) can be done alone or as a double muscle transfer for elbow flexion and finger flexion. The wrist can be fused to enhance hand function if it is unstable, especially in global lesions. The thumb may be imparted stability by either arthrodesis or tenodesis. The objectives of this study are to establish the time of intervention, assessment of outcome in various muscle and tendon transfer procedures, to evaluate the practical aspects of planning, operative technique, post-operative management and complications, and to compare, whenever feasible, the results of different procedures aimed at producing similar movements.

Timing of surgery : It is unwise to perform primary brachial plexus repair more than 9-12 months after initial injury. The results of muscle grading after nerve reconstruction, either by direct repair or by use of nerve grafts or nerve transfers are usually significantly better when the denervation time is less than six months in comparison to procedures performed more than 1 year after injury. In chronic cases (one year after injury), the muscles tend to undergo atrophy, with muscle fibre being replaced by connective tissue and fat. Delayed nerve repair in such circumstances is useless and usually leads to poor results.

Material and Methods

A total of 19 patients underwent 20 delayed procedures between November 2010 and October 2013. The age of the patients ranged from 3 to 50 years. All 19 patients included in the study were males. Selection criteria included patients who presented late (>nine months) without spontaneous recovery; who showed no improvement on primary surgery; and those who failed on conservative measures. Exclusion criteria included stiff joints with advanced degeneration and uncooperative patients.

An informed consent was taken from all patients. Work up included details of age, occupation, hand dominance, denervation time, associated injuries, paraesthesia and numbness, recovery of functions, any previous surgical intervention use of splintage and physiotherapy. General examination included signs of Horner's syndrome, associated injuries like bone fractures and vascular injuries. In detailed local examination, Medical Research Council (MRC) Grading for power and sensation, Tinel's sign, vascular status and winged scapula were documented. Radiologic evaluation included X-ray (cervical spine, chest, shoulder with clavicle and scapula) and MRI. Electrodiagnostic studies were done both preoperatively and also on follow up. Preoperative & postoperative photographs and videos demonstrating the active movement of all joints as compared to the normal side were taken. Evaluation was done for muscle power, range of movements, pain and sensory recovery. All the patients underwent physiotherapy under supervision during the waiting time for surgery.

Prerequisites for muscle transfer are adequate joint mobility, adequate soft tissue cover, absence of edema. Donor muscle must be of adequate strength and amplitude of excursion in a motivated patient. Initially, guarded and later aggressive physiotherapy was done in the postoperative period. First follow up visit was after 3 months of surgery. Patients were reviewed with clinical examination, photographs, videos and electrodiagnostic studies. Thereafter, the visits were 3 monthly for first one year, and then 6 monthly for next two years. Postoperative functional grading was done with: M0 - M1=Poor result, M2=Fair result, M3=Good result, M4 - M5=Excellent result.

Results

The age of the patients ranged from 3 to 50 years, with nearly half of them (52.6%) being in 21 to 40 years age group, (mean 27.36 yrs). All patients were males and right hand dominant.

In our study, right-sided was involved in 13 cases (68.4%) as compared to left in 6 cases (31.6%). 15 patients (78.9%) had brachial plexus injury due to road traffic accident, 2 cases (10.5%) had obstetric brachial plexus injury, 1 patient (5.3%) sustained injury due to fall from height while 1 patient (5.3%) had blunt (assault) injury. Patients also sustained other associated injuries, none having multiple injuries (Table.1). Most common site of brachial plexus injury was upper trunk in 7 cases (36.8%). Next common in frequency was involvement of C5-7 and C5-8, T1 which was present in 5 cases (26.3%). 1 patient had rupture of C5, 6 roots and isolated lower trunk was involved in 1 patient (Table 2)

Three out of 19 patients had previous surgical intervention for brachial plexus injury. First patient had neurolysis of upper trunk without any improvement who later underwent latissimus dorsi muscle transfer for elbow flexion and trapezius muscle transfer for shoulder reconstruction. Second patient who also had neurolysis underwent Oberlin's 1 procedure and the third patient required free gracilis for elbow flexion and fingers extension.

For the procedures, the denervation time for shoulder reconstruction was 12-36 months The denervation time for restoration of elbow function was 12-24 months (range, 9-30 months).

In the present study, total of 19 patients underwent 20 procedures: 7 trapezius transfers, 12 procedures for elbow flexion ± fingers flexion/extension and 1 tendon transfer for patient of obstetric brachial plexus injury (transfer of pronator teres to extensor carpi radialis brevis for wrist extension and palmaris longus to extensor pollicis longus for thumb extension) (Table 3).

For elbow function, free functioning gracilis muscle transfer was done in 9 cases (75.0%) (Table 4). It was used for restoration of only elbow flexion in 5 cases, for both elbow and fingers flexion in 2 cases, and for both elbow flexion and fingers extension in 2 patients. The other 3 procedures for restoration of elbow flexion included pedicled latissimus dorsi muscle transfer (Fig.1), Oberlin's 1 and Oberlin's 2 procedure (Fig 2,3 &4).

Functional results for shoulder abduction were graded into four categories. Out of 7 patients, 1 patient achieved excellent function (M4) and 2 showed good (M3) results (Fig 5 & 6), 1 patient could achieve M2 power and 1 patient had a poor function. There was no significant difference in the outcome of shoulder reconstruction in relation to the denervation time (p value=0.537) (Table 5)

Functional results for elbow flexion were also graded into four categories. Most of the patients in our study were able to achieve good results. Out of 12 patients who underwent restoration of elbow flexion, 1 patient showed excellent result (M4) while 6 patients achieved M3 power (Fig7 & 8). 2 patients had M2 power and the other 3 patients showed poor function. There was no significant difference in the outcome of elbow flexion in relation to the denervation time (p value=0.387 (Table.6). Follow up period was 12-30 months with a mean of 16 months.

Table 1: Distribution of the associated injuries

Associated Injuries	Frequency	Percentage (%)
None	10	52.6
Head Injury	3	15.8
# Rt Radius	1	5.3
# Clavicle	2	10.5
Scapula	1	5.3
Humerus	1	5.3
Mandible	1	5.3
Total	**19**	**100.0**

Table 2: Distribution of patients in relation to site

Nerve Roots Involved	Frequency	Percentage (%)
Partial C5,6	1	5.3
C5,6	7	36.8
C5,6,7	5	26.3
C8, T1	1	5.3
C5,6,7,8,T1	5	26.3
Total	**19**	**100.0**

Table 3: Distribution related to type of delayed procedure (n=20)

S. No.	Type of Procedure	Movements restored	No. of patients
1.	Trapezius	Shoulder abduction	7
2.	Free gracilis	Elbow flexion	5
3.	Free gracilis	Elbow & fingers flexion	2
4.	Free gracilis	Elbow flexion & fingers extension	2
5.	Latissimus dorsi	Elbow flexion	1
6.	Oberlin's 1	Elbow flexion	1
7.	Oberlin's 2	Elbow flexion	1
8.	Tendon transfer	Wrist & thumb extension	1

Table 4: Distribution of free Gracilis muscle transfers for irreparable brachial plexus injury (n=9)

Site of injury	Denervation time (months)	Number of cases	Restoration of function
C5-8, T1	14	1	Elbow Flexion
C5-8, T1	18	1	Elbow & fingers flexion
C5-8, T1	15	1	Elbow flexion & fingers extension
C5-8, T1	15	1	Elbow & fingers flexion
C5,6,7	20	1	Elbow flexion & fingers extension
C5,6,7	24	1	Elbow flexion
C5-8, T1	24	2	Elbow flexion
C5,6	30	1	Elbow flexion

Table 5: Outcome after secondary procedure for shoulder reconstruction (n=7)

Time since injury		Functional Result					Total
		Awa-ited	M0- M1= Poor	M2= Fair	M3= Good	M4- M5= Excellent	
	Since birth	0	0	0	1	0	1
	>12 to 18 months	1	1	0	0	1	3
	> 18 to 36 months	1	0	1	1	0	3
Total		2	1	1	2	1	7

Table 6: Outcome after delayed procedure for elbow reconstruction (n=12)

Time since injury (month)		Outcome				Total
		M0- M1= Poor	M2= Fair	M3= Good	M4- M5= Excellent	
	Upto 12	0	1	1	0	2
	>12 - 18	1	0	3	1	5
	> 18 - 24	1	1	2	0	4
	> 24 - 30	1	0	0	0	1
Total		**3**	**2**	**6**	**1**	**12**

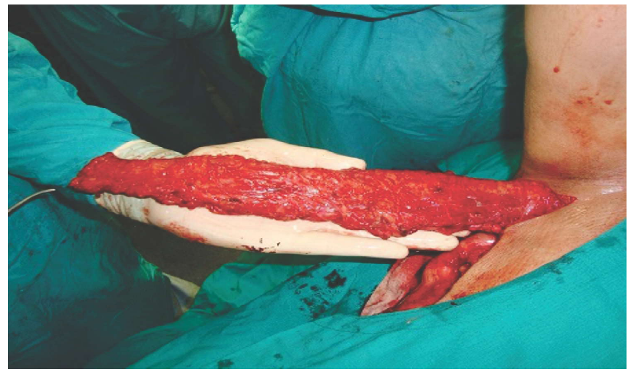

Fig. 1 Preoperative photograph showing right brachial plexus injury with 30° shoulder flexion and abduction.

Fig. 2 15 months follow up with excellent recovery with full shoulder abduction and flexion.

Fig. 3 Intraoperative photograph showing attachment of gracilis proximally to acromion process and distally to tendon of EDC for both elbow flexion and fingers extension.

Fig. 4 Postoperative photograph at 5 months follow up showing M3 power of gracilis muscle.

Fig. 5 Intraoperative photograph showing Latissimus dorsi muscle islanded on its neurovascular pedicle.

Fig. 6 Preoperative photograph showing left brachial plexus injury.

Fig. 7 Intraoperative photograph (patient shown in Figure 6) showing neurotization of ulnar nerve fascicle (to FCU) to branch to biceps and median nerve fascicle (to FCR) to branch to brachialis.

Fig. 8 Postoperative photograph (same patient shown in Figure 6) at 6 months follow up showing M3 power of biceps muscle.

Discussion

The management of brachial plexus injuries represents one of the most complex challenges. In adults, it is associated with many problems of great interest to plastic and reconstructive micro surgeons. Goals of the treatment depend on the extent of remaining function, nature of injury and denervation time. Surgery is the treatment of choice in majority of patients with brachial plexus injuries. Factors in the surgical algorithm include the timing of surgery, technique of exploration, selection of technique for repair and reconstructive strategy for treatment goals.

A variety of procedures were carried out for the management of brachial plexus injuries of different types, sites and of varied aetiology in 19 patients. All patients having isolated or multiple injuries underwent delayed reconstructive procedures as required. Thus, to compare the results and draw conclusion on basis of such a wide variety of procedures over such a varied type of injuries, with variable denervation time was difficult but in spite of that, results are encouraging. It would be wise to suggest that applicability and success of most of these procedures can best be judged over period of time.

Palliative reconstruction can be considered when the functional sequel persists after the maximal recovery either by spontaneous recovery or after nerve reconstruction. Our study is based on these delayed procedures. The basic aim was to ascertain the timing of intervention and to assess the outcome of various delayed procedures for different functions and also to compare the results of different procedures for same movement, if possible.

In the present study, 15 patients (68.18 %) had injury involving right brachial plexus. Terzis et al[2] (1999) found in her study that right sided injury occurred in 97 patients (48 %). This can be explained by a tendency to support the body whenever thrown out of balance, by dominant hand. The most common cause of brachial plexus injury in our study was Road Traffic Accident (78.9 %). In the present study 47.4 % (n = 9) patients had associated injuries with head injuries and clavicle fracture as the most common associated injury which was present in 5 patients each (26.3%). Matsuyama et al[3] also reported that associated injuries were present in 11 (68.8%) out of 16 patients, among these most common was head injury which was present in 8 patients (50%).

In the present study, total of 19 patients underwent 20 procedures: Seven trapezius muscle transfer, 8 procedures for isolated elbow flexion, 4 surgeries for both elbow flexion and fingers flexion/extension and 1 tendon transfer (Table.3). Out of 19 patients, 3 patients had an initial primary procedure for brachial plexus reconstruction. Mayer[4] reported on the use of the trapezius as a single motor for restoration of abduction of the paralyzed arm. Aziz et al[5] reported successful treatment of 27 patients with brachial plexus injury by transfer of trapezius to the proximal humerus preoperatively with an average abduction of 35. Ruhmann et al[6-8] performed trapezius transfer in 54 patients for deltoid and supraspinatous and found that there was an improvement in shoulder function and stability. Singh et al[9] treated 8 patients of brachial plexus injury with trapezius transfer by modified technique and reported an average increase in active abduction of shoulder from 13.7° to 116° and in shoulder flexion from 24.3° to 107. In our study, a total of 7 patients underwent trapezius transfer for shoulder reconstruction. One patient had upper trunk injury with deltoid M2 muscle power, shoulder abduction was 30°. Denervation time was 18 months. The trapezius muscle transfer was done. Post-operatively, he had significant improvement and achieved excellent result with deltoid M4 power. Shoulder abduction was complete. Two other patients, who had C5, 6 root rupture, presented with weakness of shoulder with abduction <30°, deltoid M1 and mild weakness of elbow flexion with M2 strength of biceps. Both of them were operated and trapezius muscle transfer was done. Post-operative result was good and with 120 degrees shoulder abduction and flexion with deltoid M3 strength.

Free muscle transfer for patients with irreparable injury is another option. It has mostly been applied for elbow flexion, finger extension and flexion, rarely for elbow extension or shoulder abduction in brachial plexus injury because of technical difficulty of elbow extension reconstruction and the complex bio-mechanism of shoulder abduction. Chuang et al[10] achieved strengths in 25 of 31 patients who had 2 or 3 intercostal nerve transfer to a free gracilis muscle transfer. Doi et al[11] described the technique of double free transfer. The procedure involves transferring first free muscle neurotized by spinal accessory nerve for elbow flexion and fingers extension, a second free muscle transfer reinnervated by 5th and 6th intercostal for finger flexion. Total of 25 patients were evaluated, the total active range of motion of fingers varied from 40° - 100° with elbow extended, the power of finger flexion varied from M2 to M5. In our study, total of 9 free functional gracilis muscle transfers were done, 5 for isolated elbow flexion, 2 for both elbow flexion and fingers flexion and 2 for elbow flexion and fingers extension (Table.4). Majority of patients (n = 5) had denervation time of 18 to 24 months and all presented after 12 months. In 2 cases, gracilis muscle necrosed in the postoperative period and flap failure occurred and in 1 case, the skin paddle did not survive and was debrided. The underlying muscle was covered with skin graft. In the outcome, 5 patients had good recovery (M3) and it was excellent (M4) in 1 patient.

In 1994, Oberlin et al[12] described a new technique of partial ulnar nerve transfer to the biceps muscle nerve for restoration of elbow flexion in traumatic C5-

C6 avulsion of the brachial plexus in adult. In our study, 2 out of 19 patients underwent Oberlin's nerve transfer for elbow flexion as delayed procedures. 1 patient with upper trunk injury without any improvement on conservative management had neurolysis at 5 months of injury. Still there was no improvement and Oberlin's 1 procedure was done at denervation time of 12 months but the patient achieved only fair result (M2) at 6 months of follow up. Another patient underwent Oberlin's 2 procedure and showed good result (M3).

Conclusion

The following conclusions were drawn from this study: the commonest age involved was 21- 40 years, with males predilection. Right upper limb was commonly injured, with the commonest etiology being road traffic accidents with fall on outstretched shoulder followed by obstetric brachial plexus palsy. The common associated injuries were head injury and fracture of clavicle, most common site being upper trunk. The postoperative outcome is not influenced by the period of denervation and hence delayed procedures need to be considered in all patients who present late (more than 9 months). Any reconstructive procedure for upper limb nerve injury depends upon the anatomical knowledge, surgical expertise, availability of donor muscles/tendons, their fixation in appropriate tension and aggressive pre - & post-operative physiotherapy. The importance of post-operative management is of utmost focus in all the delayed procedures which includes flap monitoring, maintenance of splintage and sequential physiotherapy. The final outcome depends upon the dedication of both patient and the surgical team. In our study with limited number of patients, results have been very encouraging.

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