ORIGINAL ARTICLE

COMPARISON OF EFFECTIVENESS OF HOME-BASED DONOR ACTIVATION FOCUSED REHABILITATION APPROACH (DAFRA) AND INSTITUTIONAL BASED REHABILITATION FOLLOWING UPPER LIMB NERVE TRANSFERS IN REGAINING FUNCTION

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Introduction: Brachial Plexus injuries cause devastating impact on quality of life. Management of these injuries include surgical intervention of nerve transfer and then rehabilitation post surgically to maximize the functional outcome. Rehabilitation can be institutional-based or donor activation focused rehabilitation approach. (DAFRA). Purpose of the study was to evaluate and compare the results of home-based donor activation focused rehabilitation approach and institutional-based rehabilitation following nerve transfers in upper limb. **Methods:** It is a comparative study which was conducted from January 2015 to December 2022. Patients were divided into two groups, Group A included patients who had a home-based exercise program that is DAFRA and Group B consisted of patients who underwent institutional based rehabilitation. After 3 weeks of surgery rehabilitation was started and the gain in muscle strength was recorded using Medical Research Council's (MCR) grading for muscle strength at 18 months was compared in both groups. **Results:** Total 23 patients under went 41 nerve transfers. Group A had 16 patients with 27 nerve transfers and group B had 7 patients with 14 nerve transfers. Mean age of the patients was 35.13±18.6 years in Group A while 36.57±15.62 years in the Group B. Mean gain in muscle strength in home-based DAFRA was 3.96±0.922 (out of 5) and that in institutional based rehabilitation was 3.71±0.726 (out of 5). **Conclusion:** It can be concluded that significant improvements can be gained by vigorous rehabilitation regimens either in institutions or at home targeting donor nerves. Home based DAFRA exercises are equally effective as institutional based rehabilitation.

Keywords: Brachial Plexus injury; Nerve transfer; Rehabilitation; DAFRA; Sensorimotor function; Muscle strength; MCR grading

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INTRODUCTION

Brachial plexus injuries occur in roughly 2–3% of all admissions to the trauma centre. They usually result road traffic accidents and falls. These injuries lead to debilitating upper limb nerve dysfunctions and pose patient to immense psychological distress, and socioeconomic hardship. Historically, major peripheral nerve injuries in the upper limb frequently resulted in profound and permanent functional deficits. Recently, however, the prognosis for functional recovery from many of these devastating injuries has substantially improved.[1] Management of brachial plexus injuries by nerve transfers have been in clinical practice for more than two decades now and are being increasingly employed to improve functional outcomes.[1,2]

In this management a healthy and expandable donor nerve is transferred to the injured nerve for re-innervation. Time line for nerve transfer is limited and it cannot be performed after 9–12 months of initial injury but it has significant advantage over tendon transfers and whenever nerve transfers are possible these are preferred. Post intervention rehabilitation and training is key to successful management and regain of muscle strength and ultimately function of limb.[3] During nerve transfer procedures when a donor nerve is transferred to the recipient nerve for muscle re-innervation, the cortical mapping in the central nervous system is also altered and remapping starts. Studies that have evaluated this remapping phenomenon, have found that regular and dedicated rehabilitation exercises after the surgical procedure can play an important role in this respect.[3,4]

This motor re-education during the rehabilitation programme is important for best results and is achieved by making the patient familiar with the anatomic aspects of surgery, thoroughly educating him/her about the new neural connections that have been established and rehabilitation that is required for effective results. Thus post-surgery exercises are considered an integral part of reconstruction after upper limb nerve transfers. For functional recovery following surgery, nerve transfers play half the role, rest is dependent on postoperative rehabilitation programs which aid in motor re-education and gain in muscle strength to achieve desired function.[5] Beers and colleagues found excellent results with donor activation focused rehabilitation approach (DAFRA) following nerve transfers.[6] Home-based exercises that is DAFRA is mentioned in Table-1.

This model is based on repetitive low intensity exercises of the donor nerve function leading to flooding of the new neural connections established thus helping in axonal regeneration. Post-surgery exercise strategies can be institutional or home-based. Institutional based rehabilitation includes and access to specialized rehabilitation centres with trained personnel and gadgets where under direct supervision of a physiotherapist exercises and training of patient is done. Whereas in home-based exercise programs, patient is trained by doctor to perform the exercises at home. One of the home-based rehabilitation lines is donor activation focused rehabilitation approach (DAFRA) recognize that the innervation pathway to the recipient is altered and the strength in the recipient can be enhanced by activation of the donor.[4] As the majority of the population in third world countries reside in underdeveloped areas with poor financial backup, limited available facilities, and access to specialized rehabilitation centres with trained personnel and gadgets. Also most of the patients are young individuals who are students or house hold earning professionals, visiting facilities results in many days off from work or school.[7,8]

The patients can easily follow these donor exercises at home and it does not require any special gadgets. After proper education of the patient they can easily practice DAFRA at home during the post op recovery phase with 3 monthly follow up. However, for post procedure institutional-based rehabilitation punctuality on part of the patient is mandatory so that the exercise sessions are not missed and are performed in specialised institutions under direct supervision.

Pakistan is the 6th most populous country of the world with almost 64% of rural population. About 60.2% of population is economically deprived and have difficulty accessing the basic health care facilities. In Pakistan much work has been done to improve the acute health care sector but the post-acute care including the rehabilitation is far from being developed at many levels. Hence there is significant shortage of trained rehabilitation professionals for a population of >180 million.[9] Management of brachial plexus injuries (BPI) is challenging. Choice of the surgical procedure depends on type of injury, nerves involved and time since injury.

Our study population mostly lives in far rural areas and their institutional based rehabilitation is not effortless. So, to address above mentioned difficulties and gain the maximum results, we opted to educate the patients for home-based rehabilitation that is DAFRA and follow it in suitable and willing patients. This provided us the lead for our study to evaluate the effects of home-based exercises after nerve transfers for upper limb nerve injuries and compare it with established institution-based rehabilitation in terms of gain in muscle strength using Medical Research Council's (MCR) grading.

MATERIAL AND METHODS

It was prospective study conducted at the Department of Plastic and Surgery, Fauji Foundation Hospital, Rawalpindi from January 2015 to December 2022. Study was initiated after ethical approval from the institutional review board. Patients were divided into two groups, Group A included patients who opted for a home-based DAFRA and Group B consisted of patients who chose institutional based rehabilitation. Sampling was done using convenient non probability sampling technique. Muscle strength was clinically evaluated using medical research council (MCR) grading and it was documented from zero to 5, with 5 being normal strength and zero being no movement at all. Patients who had muscle strength of 0/5 initial assessment of brachial plexus injury, did not show any evidence of recovery at 3 months in the territory of injured nerve on electrodiagnostic studies and who underwent nerve transfers within 6 to 9 months of injury were included in study. The patients with age >70 years, patients who lost to follow and patients who had muscle power of >0/5 at initial assessment were excluded from study. Post intervention strength of muscle was noted at 12 months follow up.

Detailed counselling of the patient was done regarding anaesthesia, surgical procedure (donor, recipient), weakness of donor (partial nerve sacrifice), post-surgical recovery, post-operative rehabilitation protocol, time taken by nerve regeneration that is "a millimeter a day", "an inch a

month”,” a foot and a half a year”. Consent for surgery was obtained. The clinical data comprising of the patient’s detailed history, clinical findings, investigations including electro diagnostic studies including nerve conduction velocity studies (NCS) and electromyography (EMG), MRI and follow-up notes were documented. Pre- and post-operative pictures and videos of patients were also recorded after their informed consent. All data were recorded in a predefined proforma and were analysed using SPSS 20. Mean improvement in muscle strength with standard deviation was calculated in both the groups and means were compared using t-test with p-value <0.05 as significant. Gradual passive exercises were started at 3 weeks post-surgery to prevent joint contractures. As the power in the innervated muscle increased with the first sign of flickering, repetition with low resistance exercises was started and increased to sets of 20–30, 4–5 times a day. No splintage of the limb was done except for radial nerve transfers to keep the fingers and wrist in extension. Patients who opted for institution-based rehabilitation were referred to rehabilitation department of Fauji Foundation Hospital, where underwent for rehabilitation under direct supervision of rehab specialist. Whereas patients who opted for home-based rehabilitation were taught exercises according to DAFRA as mentioned in Table-1.

RESULTS

A total of 23 patients were included of whom 41 procedures were performed. A mean age of 35.13±18.6 years was observed in home-based exercise groups while 36.57±15.62 years was reported in patients undergoing institution-based exercises. The most common aetiology in the home-based therapy group was Road traffic accidents (RTA) while that in the institution-based group was injection injury (Table-2).

Data of nerve transfer, target function and post intervention power of muscle at 18 months with home based DAFRA were recorded as shown Table-3. Mean gain in power was 3.96/5 (±0.922). Seven targeted functions recovered to full 5/5 power, 11 recovered 4/5 power, 6 gained 3/5 power and two gained 2/5 power.

Statistics of nerve transfer, target function and post intervention power of muscle at 18 months with institution-based rehabilitation protocol showed that 14 procedures were performed to target specific functions as shown in Table. No. 4. Mean gain in power was 3.71±0.726 (out of 5). Two targeted functions recovered to full 5/5 power, 6 recovered 4/5 power and 6 gained 3/5 power.

It was noted found that home-based therapy is as effective in improving patient outcome in terms of regaining muscle power as institutional-based physiotherapy, as the difference was statistically insignificant Table-5.

Table-1: DAFRA protocol

Nerve Transfers	Exercises Advised
Nerve transfer for Elbow function	Double fascicular transfer: Active fisting and wrist ROM Squeezing the ball in hand Flexion of the elbow against resistance Active assisted elbow flexion while gripping the fingers and flexing the wrist Place and hold while contracting the donor Intercostals nerve to musculocutaneous nerve: Inhalation, exhalation(deep breathing) climbing stairs
Nerve Transfer for Shoulder function	SAN to SSN Shoulder shrug Backward shoulder rolls to bring scapular blades together Shrugging against resistance Abduction and external rotation with active scapular elevation
	Triceps branch to axillary nerve: Extension of arm Contraction of triceps while attempting shoulder extension and abduction
Nerve transfers for hand function	FDS to ECRB and FCR to PIN Finger IP flexion and wrist extension Wrist flexion with the extension of fingers Resisted finger and wrist flexion exercises
Nerve transfer for ulnar nerve	Pronator quadratus to ulnar motor nerve Active forearm pronation Spreading of fingers with resisted forearm pronation Passive and active figure adduction and abduction.

Table-2: Demographic Data

Patient Characteristics	Group A (Home)	Group B (Institutional)	*p*-value
Age (years)	35.13 ± 18.66	36.57 ± 15.62	
Gender			0.34
Female	8 (50%)	5 (71.4%)	
Male	8 (50%)	2 (28.6%)	
Comorbidities			0.794
No comorbidities	13 (81.3%))	6 (85.7%)	
Hypertension	1 (6.3%)	0 (0%)	
Hypertension and Diabetes Mellitus	2 (12.5%)	1 (14.3%)	
Mechanism/ mode of injury			0.048
Iatrogenic	2 (12.5%)	3 (42.9%)	
Injection injury	4 (25%)	4 (57.1%)	
Road traffic accidents (RTA)	8 (50%)	0 (0%)	
Gunshot	2 (12.5%)	0 (0%)	
Concomitant injuries			0.418
None	12 (75%)	4 (57.1%)	
Fracture of humerus	3 (18.8%)	3 (42.9%)	
Fracture of scapula	1 (6.3%)	0 (0%)	
Nerves involved			0.373
High Radial Nerve Palsy (RNP)	7 (43.8%)	7 (100%)	
Global Brachial Plexus Injury (BPI)	1 (6.3%)	0 (0%)	
UNI	1 (6.3%)	0 (0%)	
Upper Brachial Plexus Injury (BPI)	3 (18.8%)	0 (0%)	
Axillary + Suprascapular Nerve (SSNI)	2 (12.5%)	0 (0%)	
Low Radial Nerve Palsy (RNP)	1 (6.3%)	0 (0%)	
Axillary	1 (6.3%)	0 (0%)	

Table-3: Home based Rehab: Nerve Transfer and Post-op muscle power

Nerve Transfers	Target Function	Post-Op muscle Power at 18 months
• ICN to MC • SAN to SSN • VUNG	• Elbow Flexion • Shoulder Abduction	• 5/5 • 4/5 • 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 4/5 • 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 4/5 • 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 3/5 • 3/5
• FCR to PIN	• Fingers Extension	• 5/5
• PQ to UN	• Hand movements	• 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 3/5 • 3/5
• Oberlin II • Triceps to AN	• Elbow Flexion • Shoulder Abduction	• 4/5 • 5/5
• Triceps to AN • SAN to SSN	• Shoulder Abduction	• 5/5
• ICN to MCN	• Elbow Flexion	• 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 2/5 • 2/5
• Oberlin II	• Elbow Flexion	• 5/5
• Triceps to AN	• Shoulder Abduction	• 5/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 4/5 • 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 3/5 • 3/5
• Triceps to AN • SAN to SSN	• Shoulder Abduction	• 5/5

Table-4: Institutional based Rehab: Nerve Transfer and Post-op muscle power

Nerve Transferred Performed	Target Function	Post-Op muscle Power
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 3/5 • 3/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 4/5 • 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 4/5 • 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 3/5 • 3/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 4/5 • 4/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 3/5 • 3/5
• FCR to PIN • FDS to ECRB	• Fingers Extension • Wrist Extension	• 5/5 • 5/5

Table-5: Comparison of Gain in muscle Power

Grade of Power	Home (n=27)	Institutional (n=14)	*p*-value
2/5	2	0	0.53
3/5	6	6	0.711
4/5	11	6	0.733
5/5	7	2	0.275
Mean Power	3.96±0.922	3.71±0.726	0.379

DISCUSSION

Management of brachial plexus injuries is not straight. Management of brachial plexus injuries (BPI) is challenging. Choice of the surgical procedure depends on type of injury, nerves involved and time since injury. One of the treatment modalities is nerve transfer and rehabilitation after the nerve transfer is as important as the surgery itself and plays a crucial role in recovery.[10] Rehabilitation protocols can be home based or institutional based. This is the first study to evaluate the effectiveness of home-based rehabilitation compared to institution-based rehabilitation specifically for upper brachial plexus injuries. Our study population mostly lives in rural areas and their institutional based rehabilitation is not that fluent due to multiple reasons. So, to address these difficulties and gain the maximum results, we opted for home-based rehabilitation that is DAFRA for suitable and willing patients. In this study, gain in muscle strength and function was as measured clinically by MRC muscle grading. The results showed that home based DAFRA is as effective as institutional based rehabilitation approach.

In a study conducted by Tung *et al*., ICN-MCN transfer was conducted after which activity-dependent strengthening of previously weak neuronal connections was done to achieve new cortical mapping and functional plasticity. The rehabilitation process brought about significant improvement in muscle power and strength.[11]

A study by Salpakoski *et al*. revealed that home-based rehabilitation programs that involved exercises, measures for safe activity, and non-pharmacologic pain management were beneficial in regaining mobility and recovery of the limb.[12] Another study conducted by Mahomed *et al*. found similar results to our study and noticed that there was no significant difference in results if home-based exercises or institutional rehabilitation programs were followed, keeping in mind the parameters of pain, the functional capacity of the limb, and patient satisfaction.[133] Similar comparisons have been conducted for other conditions, particularly stroke. Nascimento LR *et al*., in their meta-analysis, found that home-based prescribed exercises yield significant improvements in upper limb motor recovery, dexterity, and activity comparable to those achieved through institute-based exercises after stroke.[14] Similarly, Toh SFM *et al*. reported in their meta-analysis that home-based upper limb interventions were superior to conventional therapy in enhancing function. Among these interventions, home-based electrical stimulation demonstrated the most significant benefits.[15] Candio P, *et al*. has shown in his cost-utility analysis from a societal perspective including healthcare, social care and informal care costs, that home-based rehabilitation was highly cost effective in reducing not only health- and social-care costs but also societal costs. [16] Similar results were reported by Tung Y, *et al*. in their post-acute care models.[17]

Additionally, home-based rehabilitative services are generally better tolerated by patients, who report higher pain tolerance during sessions and greater satisfaction with treatment. Patients are also more likely to recommend home-based rehabilitation to family or friends. Key benefits highlighted by patients include convenience, flexible scheduling, and personalized treatment.[18] Also being in familiar surroundings helps develop a sense of comfort in the patient.[19]

Thus, it can be noted from our findings and the findings of similar studies that home-based rehabilitation programs result in a significant improvement in limb function, and range of motion of the upper extremities. This implies that home-based programs are a reasonable

alternative to an institutional rehabilitation program where there is limitations and difficulties to institutional based rehabilitation.

Our study revealed that two patients achieved no functional outcome following institutional based exercises. Recovery was probably not seen as they belong to the earliest group of patients that we operated and it may be the early point of our learning curve for nerve transfers. In addition patients did not follow proper institutional based rehabilitation. So they were excluded from study. For these patients, a second procedure i.e. tendon transfers was done following nerve transfer to achieve the desired results. Studies have shown that successful outcomes can be achieved with good rehabilitation strategies.

Limitations

Small sample size and a single institution-based study made it difficult to make effective correlations and comparisons.

CONCLUSION

In conclusion, after surgery proper rehabilitation is emphasised, whether home-based or institutional based rehabilitation. Home based DAFRA exercises are equally effective as institutional based rehabilitation. The rehabilitation techniques used in this study were hassle-free and do not require vast machinery and can therefore be conveniently practiced. It is an effective way to regain upper limb function after nerve transfers. And can be an active alternative to institutional based rehabilitation.

AUTHORS' CONTRIBUTION

NS, AA, AA: Concept, Literature search, write-up, proof reading. AA, SA, MM: Data collection, data analysis, interpretation. HF, SR, NT, AI, SH: Literature search, data collection.

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