Rehabilitation Outcome of Neurotization Procedures to Restore Elbow Flexion in Traumatic Total Brachial Plexus Injury

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ABSTRACT

BACKGROUND
Incidence of total brachial plexus-avulsion injury is on the increase and is difficult to treat. The consequences are devastating resulting in significant disability. We wanted to compare rehabilitation outcome of Spinal Accessory Nerve Transfer (SANT) to Musculocutaneous Nerve (MCN) with Intercostal Nerve Transfer (ICNT) to Musculocutaneous Nerve for restoring elbow flexion in traumatic total brachial plexus injury.

METHODS
This is a cross sectional study performed in 30 traumatic total brachial plexus injury patients at Institute of Research and Rehabilitation of Hand, Stanley Medical College, Chennai, between January 2018 and December 2019. 15 of them underwent spinal accessory nerve transfer (SANT) to musculocutaneous nerve and 15 patients underwent intercostal nerve transfer (ICNT) to musculocutaneous nerve (MCN). Post-surgery, patients were enrolled in a structured rehabilitation program with periodic follow up and assessment of biceps muscle power was performed.

RESULTS
9 out of 15 (60%) patients regained biceps muscle power 3 or more in SANT group as compared to 5 out of 15 patients (33.3%) in the ICNT group. Mean time duration for clinical reinnervation of biceps in SANT and ICNT groups were 6.1 and 9.4 months respectively which was not statistically significant. Biceps muscle score at the end of the follow up period was 3 ± 0.82 in SANT group and 2.3± 0.95 in ICNT group which was statistically significant (by Mann-Whitney nonparametric U test, U value =63.4, $p<0.05$).

CONCLUSIONS
SANT group regained greater final biceps muscle power score but there was no statistically significant difference in the rates of effective recovery between the two groups and hence we conclude that both of the procedures are equally efficacious.

KEYWORDS
Brachial Plexus, Biceps Muscle, Nerve Transfer, Rehabilitation

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BACKGROUND

Incidence of total brachial plexus-avulsion injury is on the increase and is extremely difficult to treat. The consequences are devastating resulting in significant disability. Motorcycle riders are the most vulnerable group and this particularly applies to developing countries where the number of people using two wheelers are more.[1, 2]

In total brachial plexus injury (C5-T1 nerve roots involvement) the entire upper limb is paralyzed. For these patients the highest priority is to restore elbow flexion function, [3,4,5] followed by abduction and external rotation of the shoulder,[6,7] finally restoration of wrist and hand function. Several surgical treatment strategies exist, including nerve grafting, nerve transfers, and a combination of both approaches. Neurotization or nerve transfer, in which a healthy but less valuable nerve or its proximal stump is transferred in order to reinnervate a more important sensory or motor territory that has lost its innervation through irreparable damage to its nerve. In brachial plexus injuries, extraplexal nerves such as the spinal accessory nerve, rami of the cervical plexus, or intercostal nerves are transferred onto trunks, cords, or individual nerves or else segments of the brachial plexus that maintain continuity with the spinal cord may be coapted to trunks or cords the surgeon wishes to innervate. This method is particularly indicated in root avulsion injuries that occur frequently following traction trauma to the brachial plexus.[8]

With the several surgical interventions available there is a need for outcome assessment of these surgical procedures which is essential in decision making as to which procedure is most effective. Very little data is available comparing the outcome of these surgeries to clearly indicate the most successful strategy for restoring elbow function in these patients and hence the need of this study. In the current study, Intercostal nerve transfer (ICNT) to Musculocutaneous nerve (MCN) and Spinal accessory nerve transfer to Musculocutaneous nerve (MCN) were studied to compare the rehabilitation outcome and thereby efficacy in terms of Biceps muscle strength recovery.

METHODS

A cross sectional study was performed in 30 traumatic total brachial plexus injury patients from Institute of Research and Rehabilitation of Hand, Stanley Medical College, 15 of whom underwent Spinal accessory nerve transfer (SANT) to Musculocutaneous nerve (MCN) and 15 patients who underwent Intercostal nerve transfer(ICNT) to Musculocutaneous nerve (MCN) for restoring elbow flexion function. Clinical, electrophysiological, and imaging data were used to identify the type and pattern of involvement of various elements of the brachial plexus. All the patients underwent a structured rehabilitation program, had periodic follow up and signed an informed consent form before inclusion in the study. Ethics: The procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional or regional) and with the Helsinki Declaration of 1975 that was revised in 2000. (http: //www.wma.net/e/policy/17-c_e.html.)

Inclusion Criteria

Age between 18 and 60 years, willing to participate in the study, cooperate in the rehabilitation program and regular follow up.

Exclusion Criteria

Non traumatic cause of brachial plexus lesion, history of rib fracture, history of pneumothorax, non-cooperative patients and restricted elbow range of motion.

Outcome Measure

The manual muscle test (MMT) using the British Medical Research Council (BMRC) scale[9] was performed on each patient before the surgery and every week after surgery and improvement in power of the Biceps muscle documented. In the British Medical Research Council grading system, the motor function scores are divided into 6 grades from grade 0 to 5. A grade of three or above was regarded as an effective recovery of motor function. Muscle strength was measured during elbow flexion by using the British Medical Research Council (BMRC) scale in the following way. The patient was instructed to remain in the seated position with trunk upright to avoid compensatory movements during the test. The examiner stabilized the patient's shoulder, providing the necessary support. The strength was graded as M0 when no sign of muscle contraction was observed; M1, muscle fasciculation; M2, when strength did not overcome the force of gravity; M3, when it overcame gravity, but did not overcome a resistance; M4, when it overcame gravity and also minimal resistance; M5, normal strength. The time required to obtain muscle grade 1(M1) and muscle grade 3 (M3) or more after surgery, were determined. At the end of the follow up period the final muscle grade (Final MG) was computed.

Postoperative Rehabilitation

For both the groups, the operated upper limb was immobilized in shoulder arm sling for 3 weeks with elbow at 90° flexion and shoulder at 0° abduction, 0°flexion and 80-90° internal rotation. Finger flexion and extension range of motion exercises were allowed for all patients just after the surgery. Starting from three weeks after surgery, shoulder arm sling was discontinued and they were allowed to start shoulder and elbow range of motion exercises. At 3 weeks post-operative period, electrical stimulation to biceps muscle was started along with muscle re-education exercises. Muscle re-education exercises for ICNT group was to do elbow flexion movement synchronously with respiration. For patients who had undergone Spinal accessory nerve transfer, muscle re-education exercises was to do elbow flexion movement with simultaneous shoulder shrugging. All patients underwent rehabilitation therapy daily for three to four months after surgery at our hand rehabilitation section.

After which, they continued to visit the center every two weeks and progress of Biceps muscle recovery was assessed clinically using MMT.

Statistical Analysis
Descriptive statistics were expressed as the mean and standard deviation. P value calculated with Unpaired Student's t-test and comparison performed between the two groups. Duration of time to achieve muscle grade 1(M1), muscle grade 3 (M3) and final muscle grade achieved at the end of follow up period (final MG) were compared between the two groups using the Mann-Whitney nonparametric U test. Statistical significance was set at p<0.05.

RESULTS

A detailed preoperative muscle chart was done. Biceps muscle power which is the target muscle was 0 in all cases in both the groups. In the SANT group trapezius muscle power was either 4 or 5 which is the requisite power for transfer of spinal accessory nerve to musculocutaneous nerve. The mean age in the SANT group was 32.4 ± 10.7 years and in the ICNT group was 30.67 ± 8.47 years which did not differ significantly. Mean time between injury and surgery was 7.67 ± 2.2 months for patients in SANT group and 8.87 ± 3.5 months for ICNT group, which was not statistically significant. The average time duration required for clinical reinnervation of biceps in the SANT group (flicker of movement) was 6 months (range 5 to 9 months). However in the ICNT group there was relative delay in reinnervation of biceps and was 9.4 months (range 8 to 12 months). Our results showed that SANT group required significantly less time to obtain both M1 and M3 or above than the ICNT group but was not statistically significant.

In the ICNT group, 5 out of 15 patients (33.3%) regained biceps strength of grade 3 or more whereas in SANT group the results were much better with 9 out of 15 (60%) patients regaining power 3 or more. Among the patients who had recovered antigravity strength, 4 patients (26.7%) had excellent recovery with biceps strength of grade 4 in the SANT group and only 1 patient (6.7%) in the ICNT group had excellent recovery?

Variables	SANT Group (Mean and SD)	ICNT Group (Mean and SD)	p Value
Age (years)	30.3± 8.96	29.8 ± 8.06	
Injury- Surgery (months)	7.67 ±2.2	8.87±3.5	NS
M1 (months)	6.15 ± 1.3	9.4±1.35	NS
Follow up period (months)	13.87± 2.2	17.67±1.68	NS
Final MG	3.07 ± 0.8	2.3± 0.95	<0.05

Table 1. Comparison of Statistical Values between SANT and ICNT Group

Note: M1- Time duration to achieve muscle grade 1, Final MG- muscle grade achieved at the end of follow up period, NS- not significant

5 patients (33.3%) in the ICNT group and 2 patients (13.3%) in the SANT group showed no improvement in muscle power from baseline even at the end of follow up period. There were no major complications in both the groups following the surgeries.

Final muscle grade obtained was 3 ± 0.82 in SANT group and 2.3 ± 0.95 in ICNT group which was statistically significant (by Mann-Whitney nonparametric U test, U value =63.4) P <0.05. Summary of statistical values of the two groups is shown in table 1.

DISCUSSION

Action of upper fibres of trapezius muscle is to elevate or the shrug the scapula which is supplied by spinal accessory nerve. The accessory nerve is a pure motor nerve but only one or two of its distal branches are used for nerve transfer so as to retain the normal function of the muscle. In the surgical procedure to transfer SAN to MCN the proximal branches of the spinal accessory to the upper part of the trapezius are preserved and the terminal branch dissected and divided as far distally as possible, then transposed and coapted to the musculocutaneous nerve which is then confirmed with electrical stimulation. Intercostal nerves are harvested by sub-periosteal separation of the intercostal muscles from the lower halves of the 3rd-5th or 6th ribs and coapted to the musculocutaneous nerve with or without nerve grafts and no deficit related to the transfer of intercostal nerves has been noted.

Muscle re-education exercises for ICNT group was to do elbow flexion movement synchronously with respiration. For patients who had undergone Spinal accessory nerve transfer, muscle re-education exercises were to do elbow flexion movement with simultaneous shoulder shrugging. The spinal accessory to musculocutaneous nerve transfer gained popularity from the 1970s through the publications of Kotani et al and Allieu et al.[10, 11] Songcharoen et al[12] have published on a series of 216 patients in which 72.5% cases recovered biceps of grade 3 or stronger. Samardzic et al reported 65% recovery rate with spinal accessory to musculocutaneous nerve transfer.[4] In the series published by Anil Bhatia, [13] 14 of 21 patients successfully regained biceps > grade 3 (66.6%). In our study 9 out of 15 (60%) patients regained power 3 or more which is comparable the above studies.

The use of intercostal nerve transfers for the musculocutaneous nerve was initially reported by Seddon.[14] Success rate of intercostals to musculocutaneous reported in literature is 33-87%.[15] The success rate depends on the level of the intercostal nerve transection, the number of nerves anastomosed and use of nerve graft. Chuang showed a success rate of 67%.[16] Anil Bhatia[13] reported in his study of 59 patients, 47 of them (77%) recovered elbow flexion stronger than grade 3. Compared to these studies our results differ considerably, with only 5 out of 15 patients (33.3%) regaining biceps strength of grade 3 or more. These differences in success percentages are generally justified in newer surgical techniques.

The average time duration required for clinical reinnervation of biceps in the SANT group (flicker of movement) was 6 months (range 5 to 9 months). However in the ICNT group there was relative delay in reinnervation of biceps and was 9.4 months (range 8 to 12 months). Our results showed that SANT group required significantly less time to obtain both M1 and M3 or above than the ICNT group but was not statistically significant. As per literature data, Biceps reinnervation time for both the surgical procedures varied significantly in the various studies. Coulet B et al[17] reported it to be 9.9 months in ICNT to MCN transfer and in the Waikakul's[18] series the electromyographic evidence of reinnervation was first seen at an average of 11.5 months for spinal accessory nerve transfer to musculocutaneous nerve transfer. In our study it was 9.4 months for ICNT to MCN transfer and 6 months for SANT to MCN transfer.

However despite innovations in surgical techniques, final outcome and functionality of the upper limb is often disappointing. Several factors influence the final result such as the delay between the time of injury and surgical procedure performed, surgical skill, concomitant vascular injuries, age of the patient, and the length of the nerve graft. Another least studied area is brain plasticity following nerve transfers in total brachial plexus root avulsion and the role of rehabilitation protocols in cortical reorganization. Feng et al[19] proposed, rehabilitation of affected limb should be started early for better results and for more extensive cortical reorganization.

CONCLUSIONS

Nerve transfer along with a well-structured rehabilitation program has radically improved the prospects for recovery of elbow function in traumatic brachial plexus injury. Since there is no statistically significant difference found in the rates of effective recovery, both the nerve transfer methods are considered equally efficacious.

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