RESEARCH PAPER

Presentation and Management Outcome of High Radial Nerve Palsy with Tendon Transfers

Muhammad Saaiq, MD[1]

Research performed at National Institute of Rehabilitation Medicine (NIRM), Islamabad, Pakistan

Received: 16 June 2020 *Accepted: 30 November 2020*

Abstract

Background: This randomized clinical trial was carried out to document the clinical presentation of isolated high radial nerve palsy (high RNP) and compare the outcome of triple tendon transfers.

Methods: The study included patients of all genders and ages who presented with isolated high RNP. Half of them were randomly assigned to the flexor carpi radialis set (FCR-set) of tendon transfers (group A) and a half to the flexor carpi ulnaris (FCU-set) of tendon transfers (group B).

Results: Out of 44 patients, 38 were males, and 6 were females. The age ranged from 7 years to 55 years. 26(59.09%) patients had primary RNP in association with fractures of the humerus. The postoperative mean disability of arm, shoulder, and hand score (Quick DASH-11 score) for the patients in the FCR-set of transfers was 34.54%% versus 41.81% for the FCU-set of transfers. 11 patients (25%) developed radial deviation deformity.

Conclusion: RNP was predominantly found among males of the young age group, and the majority of the cases resulted from preventable causes. The triple tendon transfers among patients of the two groups robustly restored the lost extension of the wrist and digits in a matching way. The patients also subjectively reported remarkable improvement in terms of the favorable Quick-DASH-11 scores. Radial deviation deformity occurred among half of the patients who underwent the FCU set of tendon transfers.

Level of evidence: II

Keywords: High radial nerve palsy, Flexor carpi radialis, Flexor carpi ulnaris, Quick-DASH-11 scores, Tendon transfers

Introduction

High radial nerve palsy (high RNP) represents the aftermath of damage to the radial nerve trunk. The nerve trunk spans from the posterior cord of the brachial plexus to the point of division of the nerve into its terminal sensory and motor branches at the elbow. High RNP manifests with sensory-motor deficits. The sensory deficit is relatively negligible; however, the motor deficit has serious consequences in compromised wrist and hand function. In most instances, the high RNP results from humeral shaft fractures, either directly as a consequence of the initial inciting event (i.e., primary palsy) or as an iatrogenic sequel of some form of treatment instituted for addressing such fractures (i.e., secondary palsy) (1-5).

The tendon transfers are performed among high RNP cases who have not shown any signs of spontaneous recovery or where other treatments such as nerve repair, nerve reconstruction, or nerve transfers have not produced significant recovery. The tendon transfers quickly ensure restoration of the critically important lost functions of wrist extension, fingers, and thumb extension, thus hand opening and grip strength (1, 6, 7).

The current study was undertaken to document the presentation of isolated high RNP and evaluate the outcome of tendon transfers of FCR-set versus FCU-set in terms of restoration of active ROM and motor power of extension of the wrist, fingers, and thumb, any radial deviation deformity of the wrist; and improvement in the

Corresponding Author: Muhammad Saaiq, Consultant Plastic surgeon and Head of Plastic Surgery Department, National Institute of Rehabilitation Medicine (NIRM), Islamabad, Pakistan
Email: muhammadsaaiq5@gmail.com

disability using the Quick-DASH-11 score. The primary null hypothesis was that "there is no difference in the outcome" between the FCR-set and FCU-set of tendon transfers for high RNP. Additionally, there is "no difference in the frequency" of radial deviation deformity of the wrist between the two techniques. The study's secondary aim was to document the clinical and demographic presentation of isolated high RNP in our population.

Materials and Methods

This randomized clinical trial was conducted over a period of three and a half years. (i.e., from October 2016 to March 2020) Informed consent was taken from the patients. The study followed the ethical protocols as per Helsinki's Declaration-2013 revision. The anonymity of the participants was guaranteed.

The study included patients of all genders and ages who presented with isolated high RNP of at least six months. The exclusion criteria included patients with pan-brachial plexus palsy, combined peripheral nerve injuries, cerebral palsy, musculoskeletal disorders, posterior interosseous nerve (PIN) palsy, arthrodesis wrist, and congenitally absent Palmaris longus (PL) tendon. Patients with the stiffness of the involved joints were initially optimized with physiotherapy to render the joints supple before undertaking tendon transfers.

Twenty-two patients were randomly assigned to the FCR-set of tendon transfers (group A) and twenty-two to the FCU-set of tendon transfers (group B). The two groups were matched for the demographic features and RNP characteristics. Simple random sampling was done with a computer-generated random number table. Table 1 shows the baseline demographic and clinical features of the patients included in the study. There were 26(59.09%) patients with primary RNP in association with fractures of the middle and distal third of the humerus. Ten (22.72%) patients had developed iatrogenic RNP secondary to acute orthopedic interventions for humeral fractures. Two (4.54%) patients presented with RNP in association with revision surgery for previously failed implants for humeral fractures. Two (4.54%) patients had developed RNP in association with surgical interventions to remove humeral implants. Three (6.81%) patients developed RNP following deltoid injections by non-doctors. One (2.27%) patient had RNP secondary to firearm injury where the entry wound was on the mid-arm level [Table 1].

Table 1. Demographic and entry variables among patients of the two groups

Characteristics/ Parameters	FCR group (n= 22)	FCU group (n= 22)
Age (Years)	29.09±14.23	29.68±13.54
Gender		
Male	19(86.36%)	19(86.36%)
Female	3(13.63%)	3(13.63%)
Duration (Months)	16.90±19.50	17.04±19.29
Affected side		
Dominant	17(77.27%)	18(81.81%)
Non-dominant	5(22.72%)	4(18.18%)

Among all patients, the wrist extension was restored with the transfer of pronator teres (PT) to extensor carpi radialis brevis (ECRB). The thumb extension was restored with the transfer of PL to extensor pollicis longus (EPL). The extensor digitorum communis (EDC) was restored with FCR or FCU transfer in groups A and B, respectively.

In the FCR-set of tendon transfers (group A), a volar incision was made along the distal two-thirds of the forearm slightly towards the radial side to ensure the easy harvest of the FCR, PL, and PT in particular. On the forearm's dorsal side, a relatively shorter incision was made along with the distal third in the midline. This latter incision was used to reroute EPL's tendon and identify and mobilize the EDC above the extensor retinaculum. Through the same incision, the ECRB was also identified. The PT tendon was harvested in continuity with a 4-cm cuff of periosteum from the middle 3rd radius. The EPL was divided proximal to the extensor retinaculum, mobilized in a proximal-distal direction, and lifted from the 3rd extensor compartment. A subcutaneous tunnel was created on the radial aspect of the wrist, the rerouted EPL was delivered to the volar forearm, and a Pulvertaft weave was performed with the PL. The tension was set with the wrist in a neutral position and putting maximum tension on both the PL and EPL. A second subcutaneous tunnel was created more proximally on the radial aspect of the distal forearm to effect the transfer of FCR to EDC. Pulvertaft weave was performed in an end-to-side fashion, proximal to the extensor retinaculum, setting the tension with the wrist in a neutral position and metacarpophalangeal joints (MCPJs) in full extension. The 3rd third tendon transfer was performed more proximally to affect the PT's transfer to ECRB, superficial to the tendons of BR and ECRL. The tension was set with the wrist in full extension. Tenodesis test was performed to ensure that the transfers were neither too tight nor too loose.

In the FCU-set of tendon transfers (group B), the volar incision was made more towards the ulnar volar side to effect the FCU's efficient harvest. Extensive mobilization of FCU with preservation of the neurovascular pedicle was carried out. The proximal 7 cm of the muscle belly was left alone. The muscle was divided at its insertion. The FCU was tunnelled subcutaneously on the ulnar border of the distal forearm.

Postoperatively, an above-elbow volar slab with thumb spica extension was applied. The wrist was kept extended, the MCPJs slightly flexed at 15°, and the interphalangeal joints (IPJs) were left free. The first wound dressing was changed on the 5th postoperative day. Sutures were removed on the 14th postoperative day. The splint was maintained for 6-weeks. Following discontinuation of the splint, physiotherapy was instituted with re-education for the tenodesis effect of the transfer.

The demographic profile of the patients, interventions, instituted, and outcomes were all recorded. The outcome measures analyzed included restoration of the active ROM, regain muscle power, radial versus ulnar deviation of the wrist, and the Quick-DASH-11 scores (8, 9). The scores were recorded preoperatively and 12-months postoperatively.

For the convenience of assessment, the active ROM of the extension was stratified into four categories of excellent, good, fair, and poor as per the description given by Moussavi AA et al. (10). The Wrist extension was categorized as excellent, good, fair, and poor for extension values of 0-80^0, 0, 45^0-extension lag, and 70^0-extension lag, respectively. For the fingers, MCPJs' extension was categorized as excellent, good, fair, and poor for extension values of 0-10^0, 0, 45^0-extension lag, and 90^0-extension lag, respectively. For the thumb, MCPJs' extension categorization was done as excellent, good, fair, and poor for extension values of 81-99^0, 60-80^0, 30-59^0, and 0-29^0, respectively. The ROM measurements were carried out 6-months postoperatively using a goniometer.

The patient was positioned comfortably on a sitting stool placed adjacent to the table for undertaking the goniometric measurement for recording any radial versus ulnar deviation deformity. The elbow was kept flexed at 90°, whereas the shoulder was maintained abducted at 90°. The forearm was supinated so that the palm faced towards the surface of the table. The capitate bone (which constituted the axis of radial and ulnar deviation at the wrist) was located by palpating just distal to the Lister tubercle. The goniometer's stationary arm was placed between the capitate and the lateral epicondyle of the elbow (i.e., the axis of the forearm). The movement arm was kept aligned to the dorsal aspect of the third metacarpal bone at the measurement time (11). The range of 0-20° was considered normal for radial deviation, whereas a range of 0-30° was accepted as the normal range for ulnar deviation. Figures 1 and 2 demonstrate the methodology employed for recording the radial deviation deformity [Figures 1; 2].

Regain of the lost muscle power was measured by employing the Modified Medical Research Council (MMRC) grading system. The motor power of extension of the wrist, fingers, and thumb was measured 6-months postoperatively. These measures were taken by a qualified physiotherapist who was blinded to details of the specific tendon transfer techniques undertaken among the patients.

The quick-DASH-11 scoring instrument (based on 11 questions) was employed to assess the overall upper limb function. The self-reporting questionnaire asked the patients about specific symptoms and the ability to perform specific tasks (involved in daily living, social and recreational activities) as experienced during the last week. For each of the 11 questions, a 5-point response scale was employed, ranging from 1-5. Response 1 (no difficulty) to 5 (unable to use the injured hand) represented the functional level accordingly. For each patient, the overall possible score thus ranged from 11 to 55. The values for all the questionnaires' responses were summed up and scaled to a score out of 100. This yielded a percentage where 0 represented no disability and 100 denoted the most severe disability. Higher scores hence reflected a higher level of disability and vice versa.

Statistical analysis

Following the data reported by Shao YC et al. and taking the prevalence of RNP as 12%, out of which there is a recovery rate of 88.1% (with expectant treatment and conservative procedures such as neurorrhaphy and nerve grafts), an overall 1.42% of the affected patients need tendon transfers (5). The sample size was calculated using the formula n = Z2 p q / e2. The "Z" represented the standard normal deviate for the 95% confidence interval (CI). It was constant as 1.96 error of deviation for 95% CI. The "*P*" represented the prevalence of RNP needing tendon transfers (i.e., 1.42%). The "q" represented 1-p. The "e" was the margin of error. It was set at 5% (i.e. 0.05).} So, Z2 = (1.96) 2 =3.841; *P= 1.42*% (i.e. 0.0142); q=1-0.0142(i.e. 0.9858); e=5% (i.e. 0.05), and so e2 =(0.05) 2 =0.0025; and a sample size= 21.20 patients. The principle of "intention-to-treat analysis" was followed. To discourage dropouts after enrollment, the patients who did not commit to adhere to the standard follow-up protocol were excluded before randomization. Figure 3 summarizes the study protocol followed for the trial [Figure 3].

Figure 1. Showing positioning of the patient and the anatomic landmarks for measuring any radial versus ulnar deviation deformity. The axis of the forearm is indicated by a line joining the lateral epicondyle at elbow with capitate at wrist. Also the third meta carpal bone is outlined where the movement arm of goniometer shall be kept aligned.

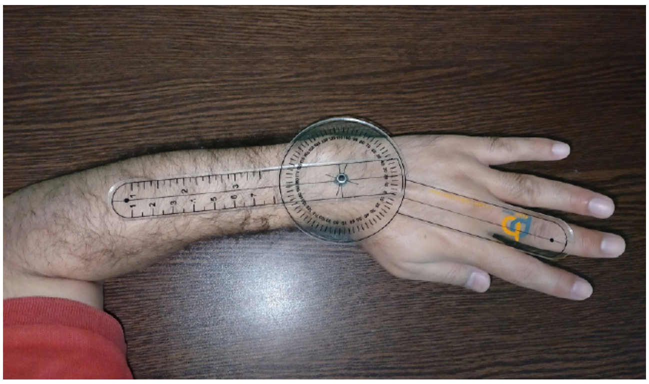

Figure 2. Showing the method for goniometric measurement. The stationary arm was placed along the axis of the forearm whereas the movement arm was kept aligned to the dorsal aspect of the third meta carpal bone at the time of measurement.

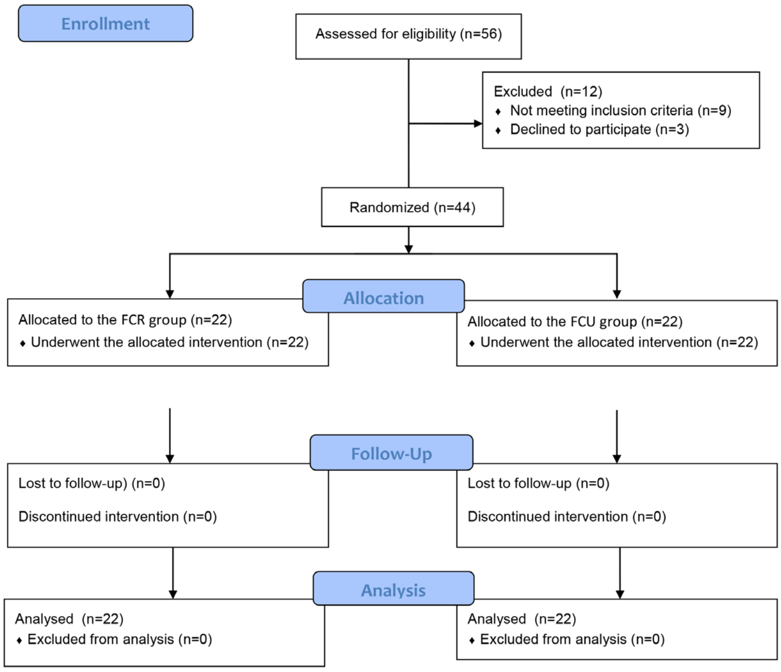

Figure 3. Flow diagram of the study protocol.

The data were subjected to statistical analysis using IBM-SPSS for Windows version 21. Frequencies and percentages were used to express the categorical data. The percentages of various variables were compared by employing the χ2 test, and *P<0.05* was considered statistically significant.

Results

There was no significant difference between the two groups regarding the restored active ROM of extension, muscle powers, and the postoperative mean Quick DASH-11 scores. The radial deviation deformity was found significantly more among patients in group B [Table 2].

Table 2. Summary of the various outcome measures compared between the two groups

Outcome Measures		FCR group	FCU group	*P-value*
Restored active ROM of extension	1)Wrist extension:			
	Excellent	19(86.36%	18(81.81%)	*P* >0.05
	Good	3(13.63%)	4(18.18%)	*P* >0.05
	2) Finger extension:			
	Excellent	3(13.63%)	2(9.09%)	*P* >0.05
	Good	17(77.27%)	18(81.81%)	*P* >0.05
	Fair	2(9.09%)	2(9.09%)	0
	3) Thumb extension:			
	Excellent	3(11.76%)	2(9.09%)	*P* >0.05
	Good	3(11.76%)	4(17.64%)	*P* >0.05
	Fair	12(58.82%)	13(59.09%)	*P* >0.05
	Poor	4(17.64%)	3(13.63%)	*P* >0.05
Restored muscle powers	1) Wrist extension :			
	Grade 4	18(81.81%)	19(86.36%)	*P* >0.05
	Grade 3	4(17.64%)	3(13.63%)	*P* >0.05
	2) Finger extension			
	Grade 4	18(81.81%)	19(86.36%)	*P* >0.05
	Grade 3	4(17.64%)	3(13.63%)	*P* >0.05
	3) Thumb extension			
	Grade 4	17(76.47%)	17(76.47%)	0
	Grade 3	5(23.52%)	5(23.52%)	0
Radial deviation deformity		0	11(50.00%)	*P* < 0.000*
Quick DASH-11 score		34.54%	41.81%	*P* >0.05

P-value <0.05* Significant

P-value >0.05 Insignificant

Discussion

This study reflects the high prevalence of RNPs in our population. The grave issue continues to plague our population; however, we could not find significant published literature on the subject from our part of the world. Our institute is a national referral center for rehabilitating disabled individuals from across the country and the neighboring Afghanistan country.

In this study, most of the cases of primary RNP occurred in association with open fractures of the middle and distal third of the humerus. Certain anatomic peculiarities and the radial nerve's course in the posterior and lateral aspects of the humerus makes it vulnerable to sustain traumatic insults. For instance, the nerve is relatively fixed at the lateral intermuscular septum and can be stretched excessively or even torn or entrapped between the fractured bone fragments (2, 5-7).

The second larger group of the patients with high RNP was constituted by those who developed the palsy as an iatrogenic sequel following various treatments for their humeral fractures. Published studies have reported a 6%-32% frequency of such mishaps. Several therapeutic interventions may result in such injuries. For instance, fracture manipulation for closed reduction, fracture fixation with intramedullary nailing using distal screws, and damage from percutaneous pins employed in external fixator (12-14). The iatrogenic injuries of the radial nerve are largely preventable. A mindful and proactive approach is prudent in this regard. At the time of surgery, routine identification and isolation of the nerve help avoid serious iatrogenic injuries. The lateral intermuscular septum and Lotem's fibrous arch should be opened to allow tensionless mobilization. Additionally, during the percutaneous treatment, a limited open approach and protection should be exercised when drilling for pin or screw insertion, especially when there is a potential rotational deformity that could make the distal position of the radial nerve even less predictable (14, 15).

In this series, one patient had palsy secondary to a firearm injury. There are limited data on such rare causes of RNP in the published papers. Rarely glass lacerations and knife cuts may also cause such injuries (15-17).

In the current study, three patients presented with RNP secondary to injections in the deltoid region. Such mishaps are certainly unacceptable in this day and age of modern medicine.

In this study, the predominant involvement of male patients was observed. Several published papers conform to our observation. Moussavi AA et al. from Iran reported 33 males and 8 females. Nalbantoglu U et al. reported 24 males versus five females in their study from Turkey. Richford J et al., in their series from Malaysia, observed 17 males and 3 females (10, 18, 19).

In this study, the bulk of the study subjects were constituted by the younger population with a mean age of 29 years. Several published studies have reported similar young age group affliction with RNP. Nalbantoglu U et al. reported a mean age of 29 years with a range of 9-51 years. Moussavi AA et al. reported a mean age of 27 years. Richford J et al. observed a mean age of 30 years (10-19, 20).

In this series, more frequent involvement of the dominant side was observed. Moussavi AA et al. reported that in 41.5% of patients, the dominant limb was involved, whereas the non-dominant limb was 58.5%. Richford J et al. observed involvement of right-sided upper limb in 65% (10-20).

In this study, the mean duration of tendon transfer after injury (paralysis time) was 16 months. Nalbantoglu U et al. reported it to be 19.7 months (range 1 day to 180 months). In this study, the tendon transfer was performed in two cases of seven years old RNP. Martínez-Villén, G et al. from Spain have reported two cases of old RNPs, one of 52 years duration and another of 30 years duration. They also observed remarkable functional recovery (19, 21).

In the present study, the established standard principles of tendon transfers were followed. We ensured adequate passive mobility of the joints, soft tissue equilibrium, and stable soft tissue coverage in all patients preoperatively. We ensured an initial 6 weeks period of immobilization following surgery. It was then followed by aggressive rehabilitation to restore the range of motion. The principles of tendon transfers have been established for a long.

In this study, the lost wrist extension was restored by employing the PT to revive the ECRB. Currently, there exists an almost universal consensus on employing the PT for this purpose. Some authorities question whether to revive only the ECRB or both ECRB and extensor carpi radialis longus (ECRL). When the extensor carpi ulnaris (ECU) function is lost, there is significant radial deviation during the wrist extension. This results in easy fatiguing and poor grip strength. To overcome this issue, Boyes JF advocates reviving both ECRB and ECRL and preserving the FCU. Brand PW initially recommended reviving only the ECRB and later on reviving the ECRB and ECU simultaneously by employing the PT (22, 23).

In this study, the lost function of thumb extension was restored by employing PL. For the thumb, restoration of the function of EPL is vital. The PL is a readily available donor to restore the function of EPL. It is rerouted subcutaneously to effect radial extension and produce some degree of radial abduction. In 20% of the population, the PL is congenitally absent. Among these patients, the other alternative options include the Flexor digitorum superficialis (FDS) and FCU tendons. In the past, some authorities strongly advocated for addressing the lost functions of the abductor pollicis longus (APL) and extensor pollicis brevis (EPB) too (2).

In the current study, the lost function of fingers extension was restored by employing FCR in group A and FCU in group B. The function of the EDC can be restored by employing one of the three available choices. i.e., FCR, FCU, and the FDS. The normal excursion of both FCR and FCU is up to 33 mm, whereas that of the EDC is 40-50 mm. This disparity does not allow them to restore the EDC's actual excursion; however, with the wrist flexion's tenodesis effect, the desired full excursion of the EDC is achieved. This requires relearning on the part of the patient (1, 2).

In the current study, most of the patients had excellent restoration of the lost extension and muscle power. The results conform to several published studies, Altintas et al. reported their long-term results among 58 cases of FCU transfers and 19 cases of FCR transfers (10, 19, 24). Overall, they observed 73%, 32%, and 80% of the wrist, fingers, and thumb's active extension, respectively, compared to the contralateral unaffected side.

In the present study, radial deviation deformity was observed among 25% of patients, and all of them had undergone the FCU-set of tendon transfers. The Radial deviation deformity is a consistent issue encountered among patients with the FCU set of tendon transfer. Nalbantoglu U et al. in their series reported it among 8 out of 29 patients (27.6%), and all occurred among those who had undergone the FCU transfers (19). Tsuge K and Ropars M et al. have also reported similar observations associated with FCU transfers (25, 26). The deformity becomes more severe if the PT is inadvertently transferred to the ECRL, a stronger radial deviator. The ECRB congenitally has some interconnections with the ECRL, so even transfer to ECRB has some effect on the action of ECRL. If the transfer is carried out in patients with preexisting posterior interosseous nerve (PIN) palsy with intact ECRL, the radial deviation becomes more exaggerated. Although not completely avoidable, some precautionary measures can be instituted to make this deformity less severe. For instance, the FCU transfer should be avoided if there is a PIN palsy or some degree of preexisting radial deviation. Some authorities have advocated certain intricate and complex modifications such as resection of the distal 2-3 cm of the ECRL tendon and suturing it more proximally into the adjacent ECRB, thereby eliminating any possibility of pulling effect through the ECRL insertion (2).

In this study, favorable improvements in the Quick-DASH-11 scores were observed following tendon transfers. The results are akin to several published papers. Moussavi AA et al. reported their mean DASH scores as 38 and 35 for the FCR versus FCU groups, respectively (10). Richford J reported an overall mean DASH score of 29.5. A Quick-DASH-11 score is an easy tool that reliably analyses tendon transfers' functional outcome among RNP patients (20). The Quick-DASH-11 is being widely employed across a range of medical ailments of the upper extremity and has demonstrated its clinical utility as a valid outcome measure.

This study has certain strengths as well as some limitations. It comprehensively documented the clinical and demographic profile of RNP patients and compared the outcome of FCR versus FCU set of tendon transfers. The limitation of the study is that the grip strength was not measured as an outcome parameter. Most of the published studies on tendon transfers for RNP have reported only 40-49% grip-strength-restoration compared to the opposite hand. Even with this grip strength, the individuals enjoy a near normal life as indicated by their favorable self-reported Quick-DASH scores (20, 24, 27).

RNP was predominantly found among males of young age groups, and most of the cases resulted from preventable causes. The triple tendon transfers among the two groups' patients robustly restored the lost extension of the wrist and digits in a matching way. The patients also subjectively reported remarkable improvement in terms of the favorable Quick-DASH-11 scores. Radial deviation deformity occurred among half of the patients who underwent the FCU set of tendon transfers.

Muhammad Saaiq MD[1]
1 Consultant Plastic surgeon and Head of Plastic Surgery Department, National Institute of Rehabilitation Medicine (NIRM), Islamabad, Pakistan

References

1. Laulan J. High radial nerve palsy. Hand Surg Rehabil. 2019; 38(1):2–13.
2. Davis TRC. Principles of tendon transfers of median, radial, and ulnar nerves. In: Wolfe SW, Pederson WC, Hotchkiss RN, Kozin SH, Cohen MS, editors. Green's textbook 7th ed. Philadelphia: Elsevier; 2017. P.1023-1079.
3. Shao YC, Harwood P, Grotz MR, Limb D, Giannoudis PV. Radial nerve palsy associated with fractures of the shaft of the humerus: a systematic review. J Bone Joint Surg Br. 2005; 87(12): 1647–52.
4. Sammer DM, Chung KC. Tendon transfers part 1: Principles of transfer and transfers for radial nerve palsy. Plast Reconstr Surg. 2009; 123(5): 169e–177e.
5. Schwab TR, Stillhard PF, Schibli S, Furrer M, Sommer C. Radial nerve palsy in humeral shaft fractures with internal fixation: analysis of management and outcome. Eur J Trauma Emerg Surg. 2018; 44(2):235-43.
6. Carlan D, Pratt J, Patterson MM, Weiland AJ, Boyer MI, Gelberman RH. The radial nerve in the brachium: an anatomic study in human cadavers. J Hand Surg Am. 2007; 32(8): 1177–82.
7. Shoji K, Heng M, Harris MB, Appleton PT, Vrahas MS, Weaver MJ. Time from injury to surgical fixation of diaphyseal humerus fractures is not associated with an increased risk of iatrogenic radial nerve palsy. J Orthop Trauma. 2017; 31(9): 491–6.
8. Beaton DE, Wright JG, Katz JN, Group UEC. Development of the QuickDASH: comparison of three item-reduction approaches. J Bone Joint Surg Am. 2005; 87(5):1038-1046.
9. Ebrahimzadeh MH, Moradi A, Vahedi E, Kachooei AR,

Birjandinejad A. Validity and reliability of the Persian version of shortened disabilities of the arm, shoulder and hand questionnaire (quick-DASH). Int J Prev Med 2015; 6:59.

10. Moussavi AA, Saied A, Karbalaeikhani A. Outcome of tendon transfer for radial nerve paralysis: Comparison of three methods. Indian J Orthop. 2011; 45(6): 558–562.
11. Vaishnani HV, Jasani JH, Gandotra A, Shah GV. A study on range of movement (radial deviation, ulnar deviation, flexion and extension) of wrist joint. Int J Health Sci Res. 2016; 6(5):94-100.
12. Claessen FM, Peters RM, Verbeek DO, Helfet DL, Ring D. Factors associated with radial nerve palsy after operative treatment of diaphyseal humeral shaft fractures. J Shoulder Elbow Surg. 2015; 24(11): e307–11.
13. Bumbasirevic M, Palibrk T, Lesic A, Atkinson H. Radial nerve palsy. EFORT Open Rev. 2017; 1(8): 286–94.
14. Reichert P, Wnukiewicz W, Witkowski J, Bochenska A, Mizia S, Gosk J, et al. Causes of secondary nerve palsy and results of treatment. Med Sci Monit. 2016; 22: 554–62.
15. Trigo L, Sarasquete J, Noguera L, Proubasta I, Lamas C. Radial nerve injury following elbow external fixator: report of three cases and literature review. Arch Orthop Trauma Surg. 2017; 137(7): 953–7.
16. Karabeg R. Assessment of the forearm tendon transfer with irreparable radial nerve injuries caused by war projectiles. Med Arch. 2019; 73(6): 415-420.
17. Taha A, Taha J. Results of suture of the radial, median, and ulnar nerves after missile injury below the axilla. J Trauma. 1998; 45(2): 335–9.
18. Murovic JA. Upper-extremity peripheral nerve injuries: a Louisiana State University Health Sciences Center literature review with comparison of the operative outcomes of 1837 Louisiana State University Health Sciences Center median, radial and ulnar nerve lesions. Neurosurgery. 2009; 65(4): A11-A17.
19. Nalbantoglu U, Ozkan T, Turkmen M. Results of tendon transfer in irreparable radial nerve palsy. Acta Orthop Traumatol Turc. 2008; 42(5):350-357.
20. Richford J, Abdullah S, Norhafizah M, Juliana I, Rashdeen F, Razana A. Outcome of tendon transfers for radial nerve palsy in a Malaysian tertiary centre. Malaysian Orthop J. 2018; 12 (1): 1-6.
21. Martínez-Villén, G, Muñoz-Marín, J, Pérez-Barrero P. Are tendon transfers justified in very old hand radial palsies? J Plast Recon Aesthetic Surg. 2012; 65(10):e293-e296.
22. Boyes JH. Tendon transfers for radial palsy. Bull Hosp Joint Dis. 1960; 21:97–105.
23. Brand PW. Clinical Mechanics of the hand. St Louis: CV Mosby; 1985.
24. Altintas AA, Altintas MA, Gazyakan E, Gohla T, Germann G, Sauerbier M. Long term results and the disabilities of the arm, shoulder, and hand score analysis after modified brooks and d'Aubigne tendon transfer for radial nerve palsy. J Hand Surg Am. 2009; 34(3):474–478.
25. Tsuge K. Tendon transfers for radial nerve palsy. Aust N Z J Surg. 1980; 50(3):267–272.
26. Ropars M, Dreano T, Siret P, Belot N, Langlais F. Long-term results of tendon transfers in radial and posterior interosseous nerve paralysis. J Hand Surg Br. 2006; 31(5):502–506.
27. Dabas V, Suri T, Surapuraju PK, Sural S, Dhal A. Functional restoration after early tendon transfer in high radial nerve paralysis. J Hand Surg Eur. 2011; 36(2): 135-40.