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New Functional Evaluation Scheme - Modality of the Results of Forearm Tendon Transfers Evaluation in Cases of Irreparable Radial Nerve Injury

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ABSTRACT

Introduction: There are several evaluation schemes for the results of tendon transfers in case of radial nerve paralysis, and the most logical and commonly used are evaluation schemes that use the range of active joint movements to evaluate the results. **Aim:** Present an original evaluation scheme for tendon transfer results based on functional wrist and fingers joint movements. The aim of the article is to present the advantages of our own Functional scheme in comparison with other schemes, its simplicity and applicability in the evaluation of all clinical cases of different postoperative outcome of the variables being evaluated, and to present the ease of comparison of the achieved results with other authors who would possibly use our scheme because it minimizes the subjective error of the examiner. The secondary aim is to compare the results of flexor carpi radialis (FCR) vs. flexor carpi ulnaris (FCU) tendon transfers (TT). **Methods:** The study was conducted as clinical and retrospective. The study included 60 patients with isolated radial nerve palsy operated by two tendon transfer surgical methods (FCR and FCU) over a 10-year period. The evaluation of the results was performed by using Zachary, Neimann-Pertecke, Tajima evaluation schemes, our own Functional Evaluation Scheme as well as subjective patient evaluation. **Results:** The time elapsed from injury to surgery ranged from 105 to 956 days in case of FCR tendon transfer and from 109 to 712 days in cases of FCU tendon transfer. The overall average age of patients is 36.71 years. A statistically significant difference in values with t -test based on the Functional Evaluation Scheme was found in the variables of ulnar deviation (p=0.000731), extension of the MP fingers joints II-V (p=0.04610) and extension of the MP of the thumb joint (p=0.0475). Evaluation of the total results with t-test (p=0.007532) and with U-test (p=0,00433) showed statistically better FCR tendon transfer results. A statistically significant difference in value measured by the t-test was found in the evaluation of the overall results (p=0.022) with Zachary and Neumann-Pertecke schemes and by the Tajima evaluation Scheme (p=0.042) in favor of better FCR tendon transfer results. With a use of Functional Evaluation Scheme, it is possible to evaluate all the results unlike most available schemes. **Conclusion:** The functional evaluation scheme is based on the functional joint movements evaluated and incorporating radial and ulnar deviation of the wrist (RD and UD), extension of the metacarpophalangeal (MCP) joint and flexion of the intephalangeal (IP)joint of the thumb in the final evaluation becomes completely original. A functional evaluation scheme is simply applicable for the evaluation of all clinical cases of different postoperative outcome of the variables being evaluated. FCR tendon transfer achieves better results than FCU TT.

Keywords: tendon transfer, radial nerve, new evaluation scheme.

1. INTRODUCTION

The etiology of radial nerve (RN) injuries is usually direct, rarely, indirect trauma. Sharp lacerations usually result in nerve intersection and firearm injury by neuropraxia or axonotemesis, extremely rarely by neurothesis (1-6). The incidence of RN injury associated with humeral fracture is from 1.8% to 16% (1-6). In the case of firearm war injuries, the incidence of injury to the RN and upper arm is higher, and usually with a fracture of humerus , it is a neuropraxia of the RN, and in peacetime injuries, it is more often isolated radial nerve injuries (4, 5). Such high RN paralysis associated with a fracture of the humerus may be secondary to nerve contusion or involvement in the fracture GAP during injury or closed reposition. Late pinching may result from callus forming in the fracture zone (7). The most common clinical presentation after radial nerve injury is represented by paralysis of all ex-

tensor muscles of the hand and fingers (a typical „wrist drop"). RN injuries usually occur below the branch for the triceps muscle of the upper arm, and extension of the elbow joint is possible in such cases (2, 3, 5). Traditionally, radial nerve palsy is divided into high and low types. It is necessary for the surgeon to distinguish complete radial nerve palsy from deep branch paralysis RN (low type,interosseal nerve palsy) (1, 2, 3, 5). There are two ways to treat radial nerve injury: a) Nerve repair (neurorraphy - primary, primary delayed and secondary) and rarely neurolysis, usually neuroplastic in the sense of a (sural) nerve transplant to replace a nerve defect that is a secondary procedure; b) Tendon transfer (TT) of the forearm.

A tendon transfer is the separation of a tendon or tendon insertion of a muscular tendon unit and its reinsertion to another tendon or bone to compensate for lost function (3, 8, 9). Irreparable damage to the radial nerve was considered a condition of failure of function when surgical treatment from the aspect of medical standards would not provide a motor response after reconstruction due to: local finding (defects of the radial nerve over 10 cm with a neat soft tissue cover on the path of expected sprouting, defects of the radial nerve over 8 cm if these are high damage combined with large skin defects in the expected RN growth path) and elapsed time to the expected reinnervation. We applied Seddon's nerve regeneration rule: after nerve reconstruction or expected spontaneous nerve recovery, in order to pass an indication for tendon transfer, we waited 12 weeks after expected nerve motor recovery at the most proximal neuromuscular point according to 1-2 mm/24 h nerve regeneration rules. It seems extremely important in setting the indication for performing TT to bear in mind that there is no upper time limit for the reconstruction of radial nerve paralysis by tendon transfer (3, 8, 9-11) There are over 40 described tendon transfer (TT) methods and their modifications for compensation lost functions of wrist extension and fingers extension in RN paralysis. So far, there is no generally accepted „best" tendon transfer (3). The four tendon transfers stood out from the rest and are considered „better". Two of them are the subject of our work (flexor carpi radialis (FCR) vs. flexor carpi ulnaris (FCU TT). The aim of the surgical procedure is to replace the lost functions of the wrist, fingers and thumb extensions. One innervated (with median or ulnar nerve) forearm tendon is transferred for each of these functions. Several schemes have been published to evaluate the results of tendon transfers in radial nerve palsy (3). The most logical and commonly used are the evaluation schemes used to evaluate the results (Active Range of Joint Movement (AROM)). Here are the Starr, Tajima, Chuinard and Neumann-Pertecke schemes that group the quality of function-result recovery into 4 groups as follows: excellent (very good), good, satisfying and poor (3, 12-15). The Zachary scheme also considers AROM but results in percentages (minimum 0%, maximum 100%) (15). It is extremely difficult or not at all possible to determine the final overall score because the results of commonly evaluated variables (wrist, fingers and thumb movements) belong to different grades. Standarisation of the results in tendon transfers are difficult (3, 12-15).

2. AIM

The primary objective of the article is to present an original Functional evaluation scheme of tendon transfer results based on functional movements of the wrist and finger joints. To evaluate and present the ease of comparing the results achieved with other authors who would possibly use our scheme as it minimizes the subjective error of the examiner.

The secondary aim is to offer the Functional Evaluation Scheme for acceptance as relevant for evaluating the results of tendon transfers in irreparable radial nerve damage.

The tertiary goal of the article is to evaluate the achieved TT results and to compare the FCR vs. FCU TT results.

3. METHODS

The study was conducted as clinical and retrospective. The study included 60 patients operated by two surgical methods of tendon transfer. Thirty-two patients with irreparable radial nerve damage were operated by FCR TT method (Figure 1) and 28 patients by FCU method in the period 1993-2003. The patients with isolated irreparable radial nerve injury were operated by FCR and FCU surgery in the Federation of Bosnia and Herzegovina over a 10-year period was included. The only difference between these transfers is donor tendon for extension of the digits (FCR vs.FCU).

Inclusion criteria: isolated radial nerve dysfunction, normal median and ulnar nerve function, normal patency of radial and ulnar artery, patients of both genders of all ages, patients undergoing FCR and FCU tendon transfer.

Exclusion criteria: Patients who could not be found for evaluation after tendon transfers of FCR and FCU. Radial and ulnar arterial injury or median and ulnar nerve injury.

Our own Functional Scheme evaluates 10 functions of wrist and finger movements (Table 1). The presented Functional Evaluation Scheme evaluates the movements of the wrist, fingers II-V and thumb on the basis of functional AROM.

The results of tendon transfers were evaluated in period from 2 to 12 years after surgery. Four outcome evaluation schemes were used: Functional Evaluation Scheme, Zachary, Neumann-Pertecke, and Tajima as well as subjective evaluation of patients. When treating patients, we used standard methods used to evaluate tendon transfers. Patients were evaluated in the morning. They were warned not to do any physical work five days before the start of the examination. Measurements were made with a wrist goniometer and a goniometer used to measure the movements of small wrist joints - three times for each movement required. If the values did not deviate more than 5%, their mean value was calculated. Evaluation of wrist movement was performed with bent fingers in fist. The evaluation of the MCP movement of

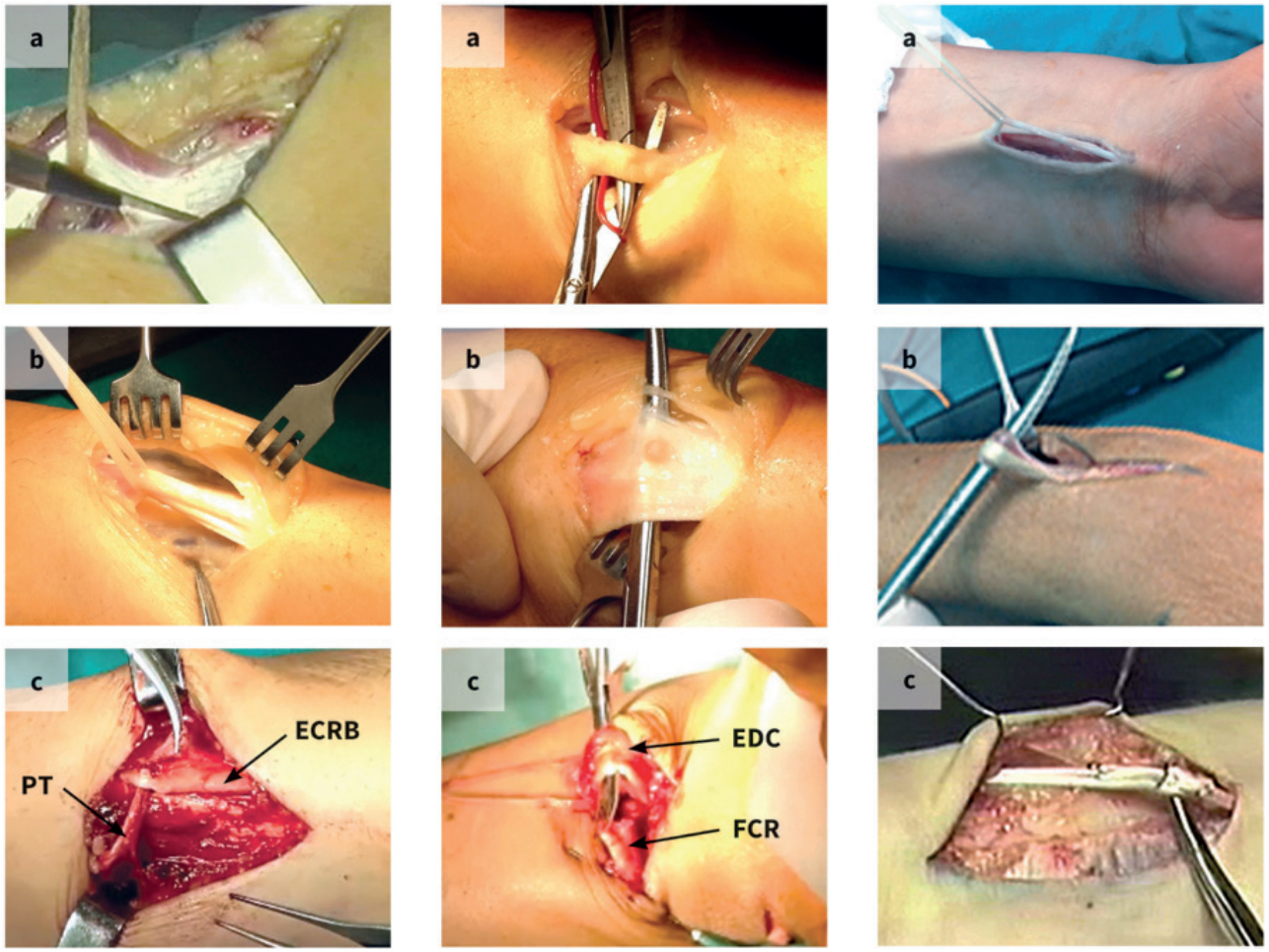

Figure 1. FCR tendon transfer. First row, donor tendons. PT-Pronator teres (left); FCR-flexor carpi radialis (middle); PL-palmaris longus (right).Second row, recipient tendons. ECRL and ECRB-extensor carpi radialis longus et brevis (left); EDC-extensor diggitorum communis (middle); EPL-extensor pollicis longus (right). Third row, transfer. Extension of the wrist: PT- ECRB (left) ;extension of the fingers: FCR-EDC (middle); extension of the thumb:PL-EPL (right)

the finger joints II-V was done with the bent fingers in the "claw hand" and at the wrist position of 30 degrees extension. A total of 10 variables were measured according to the scheme. MCP extension of the II-V finger was measured with bent fingers in the hand (maximal flexion of the proximal and distal interphalangeal joints) and at the wrist position at 30 degrees of extension and neutral.

Each of the ten functions (rated variables); based on the measurement, receives a rating of 1, 2, 3 or 4. A excellent performance is given a score of 4, a good performance is a score of 3, a satisfactory performance is a score of 2, and if the function is without improvement, a score of 1. The minimum final score is 10 points. The maximum score measures 40 points. The end result can be: Excellent (36-40 points; grade point average 3.6-4.0); good (25-35 points; grade point average 2.5-3.5); satisfactory 18-24 (grade point average 1.8-2.4), poor <18 (grade point average <1.8). A maximum of 2 functions are allowed to be without enhancement. Regardless of the total number of points, if 3 functions are without improvement, the result is considered poor.

The three basic functions compensated for by tendon transfer surgery are the extension of the wrist, fingers and thumb. Considering these important facts, if more than one of these functions is judged to be poor, the end result is considered to be poor regardless to the total number of points.

Statistical analysis

The results are presented by the number of cases, percentage, arithmetic mean and standard deviation. The statistical processing was done with Student's t-test, Chi-square test and Mann-Whitney method (U-test). All analysis results with $p < 0.05$ or 95% confidence level were considered statistically significant. The SPSS Windows software package (version 21.0, SPSS Inc, Chicago, Illinois, USA) and Microsoft Excell (version 11. Microsoft Corporation, Redmond, WA, USA) were used for statistical analysis of the data obtained. The research license was obtained by the Ethics Committee, Clinical Center University of Sarajevo, Bosnia and Herzegovina.

4. RESULTS

Radial nerve injuries in 55 patients (92%) were the result of war wounding in 1992-1995. After 1996, 5 patients (8%) who were not injured by firearms were operated. Injuries occurred as a result of incidence wounds in traffic accidents (2 patients) and the result of incision wounds (3 patients). Fifty-three patients (88.33%) are male and seven (11.67%) are female. Twenty patients (33.33%) are in the age group up to 30 years, 22 patients (36.60%) are in the age structure of 31-45 years. In the age group of

GRADE		Excellent (4)	Good (3)	Satisfactory (2)	Poor (1)
Wrist	DF	>35°	15-35°	-10 do 14°	<-10°
	PF	>35°	15-35°	1-14°	inability of flexion
	RD	>15°	10-15°	1 - 9°	inability of RD
	UD	>20°	10-20°	1 - 9°	inability of UD
Fingers	MPE	>170°	155-170°	140 - 154°	<140°
	FT-MPC	0	do 1,5 cm	1,5 – 3,0 cm	>3,0 cm
Thumb	ABD	>40°	25-40°	10 - 24°	<10°
	MPE	>175°	160-175°	<160°	without improvement
	IPE	>175°	160-175°	145 - 159°	<145°
	IPF	>60°	40-60°	20 - 39°	<20°

Table 1. Functional evaluation scheme (DF-dorsal flexion-extension, PF-palmar flexion, RD-radial deviation, UD-ulnar deviation, MPE-metacarpophalangeal extension, FT-MPC-fingertip distance II-V to the central furrow of the fist, IPE-interphalangeal thumb extension, IPF-interphalangeal thumb flexion)

itself, mainly due to war circumstances-they came too late or the local situation did not allow reconstruction of the nerve. Primary tendon transfer was performed in next 3 patients (5%) after exploration and examination of the severity of radial nerve injury. The average time elapsed from injury to primary transfer surgery is 106 days. Forty four patients (73.33%) underwent surgery under general anesthesia, 16 patients (26.67%) underwent surgery under regional anesthesia, and the time elapsed from injury to surgery ranged from 105 to 956 days with FCR tendon transfer and from 109 to 712 days at FCU tendon transfer. The minimum total time was 105 days, the maximum 956 days. The average time elapsed from injury to surgery for FCR tendon transfer is 504.67 days. With FCU tendon transfer it is 396.02 days. The total average time to surgery for tendon transfer is 450.35 days.

Comparison of the two methods by the functional evaluation scheme is presented in Table 2. A statistically significant difference in T-test values was found for ulnar deviation variables (p=0.000731), extension of the MP of the finger joint II-V (p = 0.0461), and extension of the MP of the thumb joint (p=0.0475), which shows better

		FCU TT	FCR TT				FCU TT. patients	FCR TT. patients	Std.Dev.	Std.Dev.	F-ratio	p
		G 1:1	G 2:2	t-value	df	p	G 1:1	G 2:2	G 1:1	G 2:2	variance	variance
wrist	DF	3.64286	3.71875	-.54336	58	.588967	28	32	.558721	.522671	1.142701	.715669
	PF	2.71429	2.90625	-.79553	58	.429550	28	32	.896790	.962503	1.151919	.713415
	UD	1.89286	2.81250	-3.56759	58	.000731	28	32	1.100144	.895779	1.508335	.269383
	RD	3.35714	3.15625	.78554	58	.435336	28	32	.911421	1.050633	1.328815	.456402
Fingers II-V	MPE	2.92857	3.40625	-2.03814	58	.046104	28	32	.939999	.874712	1.154847	.694713
	FT-MPC	3.67857	3.62500	.26421	58	.792551	28	32	.772374	.793116	1.054431	.894627
Thumb	ABD	3.17857	3.46875	-1.67239	58	.099834	28	32	.772374	.567074	1.855136	.098330
	MPE	3.14286	3.50000	-1.93754	58	.047554	28	32	.755929	.672022	1.265306	.524624
	IPE	3.39286	3.43750	-.23769	58	.812958	28	32	.685257	.759350	1.227942	.591626
	IPF	3.42857	3.62500	-1.22261	58	.226421	28	32	.690066	.553581	1.553885	.236572
TOTAL SCORE		31.17857	33.65625	-2.76929	58	.007532	28	32	3.878273	3.043866	1.623401	.193654
RESULTS		3.07143	3.46875	-2.93934	58	.004715	28	32	.465759	.567074	1.482371	.302194

Table 2. Functional evaluation scheme. Comparison of the two methods (FCU TT-flexor carpi ulnaris tendon transfer, FCR TT–flexor carpi radialis tendon transfer; p-significance, DF-dorsal flexion, PF-palmar flexion, RD-radial deviation, UD- ulnar deviation, MPE-metacarpophalangeal extension, FT-MPC distance of fingertips II-V to the central furrow of the fist, IPE-interphalangeal thumb extension, IPF-interphalangeal thumb flexion, ABD–abduction).

46-60 years there are 13 patients (21.67%) and 5 patients (8.33%) were over 60 at the time of surgery. The youngest patient was 23 years old at the time of tendon transfer surgery and the oldest patient was 77 years old. The average age of patients undergoing FCR tendon transfer is 36.19 years, and for patients undergoing FCU surgery is 37.23 years. The overall average age of patients is 36.71 years. At the level of the upper arm, 42 patients (70%) were injured. At the elbow level, 6 patients (10%) were injured. Twelve patients (20%) were injured at forearm level.

Type of surgery performed on the radial nerve before TT: secondary neurorraphy was done in 3 patients (5%), nerve transplantation was done in 4 patients (6.67%). Only 7 patients (11.67%) had reconstruction of the nerve result of FCR tendon transfer. A statistically significant difference in value was also found when evaluating the total scores (p=0.00753) in favor of FCR tendon transfer.

A statistically significant difference in the value of the U-test was found in the variables of ulnar deviation (p=0.0135) and extension of the MP of the finger joint II-V (p = 0.028) in favor of a better FCR tendon transfer result. A statistically significant difference in value was also found in the evaluation of the overall results (p=0.00443) in favor of better results achieved by FCR tendon transfer. Overall results, based on the Functional Evaluation Scheme, were evaluated by Chi-square test (Table 3).

As presented in Table 3, for FCU tendon transfer, overall, very good result was achieved in one patient, good

Score	36 - 40	25 - 35	18 - 24	<18	TOTAL	
Grade	(4)	(3)	(2)	(1)		
FCU TT	1	26	0	1	28	Patients
	3.57%	92.85 %	0.0 %	3.57%	100 %	%
FCR TT	9	21	1	1	32	Patients
	28.12 %	65.62 %	3.12 %	3.12%	100 %	%
TOTAL (FCR +FCU TT)	10	47	1	2	60	Patients
	16.7 %	78.33 %	1.67 %	3.33%	100 %	%
X2=8.6294 df=2 p< .004416						

Table 3. Analysis of overall results by Functional Evaluation Scheme

result in 26 patients and poor result in one patient. FCR tendon transfer overall, a very good result was achieved in nine patients, a good result in 21 patients, satisfactory in one patient and a poor result in one patient. Statistically significant (p = 0.004416) better results were obtained by FCR tendon transfer.

Based on the results achieved by tendon transfers, the number of patients who cannot be evaluated, that is,final score cannot be got by Chuinard and Tajima evaluation scheme is shown in Table 4.

FINAL SCORE THAT CAN'T BE GOT (number of patients)			
Evaluation Scheme	FCR TT	FCU TT	Total
TAJIMA	3	6	9
CHUINARD	12	7	19
FUNCTIONAL	0	0	0

Table 4. . Comparison of possibility to get final score by different evaluation schemes

Measured by the Zachary evaluation scheme, the total score in patients undergoing FCR tendon transfer was 91.20%. The total result in patients undergoing FCU tendon transfer was 81.20%. The total result of all operated patients is 86.20%. An F-ratio coefficient testing the significance of variance differences between patient groups operated by FCR and FCU tendon transfer indicates statistically significant differences (q=0.022) in favor of better FCR TT results.

Overall assessment of tendon transfer results achieved by the Tajima Evaluation Scheme. There is a statistically significant difference in arithmetic means measured by the t-test (p=0.042) in favor of tendon FCR transfer.

The subjective evaluation of patients on the results of surgery is presented in Table 5.

TRANSFER	I (Excellent)	II (Good)	III (Satisfactory)	IV (Poor)	Total	
FCR TT	19	9	4	0	32	Patients
	59.4	28.1	12.5	0	100	%
FCU TT	15	11	1	1	28	Patients
	53.6	39.2	3.6	3.6	100	%
Total	34	20	5	1	60	Patients
	56.7	33.3	8.3	1.7	100	%

Table 5. Subjective evaluation of the patient (FCU TT - flexor carpi ulnaris tendon transfer, FCR TT - flexor carpi radialis tendon transfer)

The achieved result is understood by excellent 34 patients (56.7%), good 20 patients (33.3%), satisfactory 5 patients (8.3%) and poor one patient (1.7%). A total of 54 patients (90%) of the patients considered the result obtained by transposition of the tendons to compensate for the loss of radial nerve function as very good or good.

5. DISCUSSION

Transferring a functional muscle-tendon unit to the site of a paralyzed or severely damaged muscle seems completely logical. By developing and increasing the safety of general anesthesia and the further development of aseptic and antiseptic surgery techniques, new possibilities for surgical access in general and tendon surgery were opened up. The first tendon transfer was done by Nicoladoni in 1880 (3). If tendon transfer was reserved for cases of unsuccessful or, for any reason, unintended nerve repair, it is clear that the greatest opportunity for clinical application was during and immediately after World War I (17). Robert Jones is considered to be the main innovator of tendon transfers for RN paralysis and published works after World War I are a continuation of his greatest contribution to addressing this problem (17). Zachary in a paper published in 1946, gave an important contribution to the creation of a standard method of score evaluation, which is in use by many authors today (15).

Evaluation schemes differ significantly in classification based on the measured active movements of the wrist. The authors of the evaluation schemes understand and attribute the same values of results achieved by surgery to different groups of grades. Clearly this problem can be observed with the example of wrist flexion. Chuinard classifies 30-degree wrist flexion as „excellent“ results, considers Tajima 10-degree wrist flexion „excellent“, Zachary evaluates only the wrist flexion ability to a neutral position and considers flexion up to 0 degrees as the best result, while Dunn even evaluates and does not mention wrist flexion (13-18).

The next problem arises when, because of the various possible combinations, it is extremely difficult or impossible to determine the final overall score because the results of the variables that are commonly evaluated (movements of the wrist, fingers and thumb) belong to different grades.

Guided by the goals, in this study we try to find the answer to two key questions of the problem of tendon transfer: which tendon transfer achieves better results and how best to evaluate the results of tendon transfer?

It is imperative to evaluate the results adequately and to compare them with the results of other authors. A widely accepted scheme applicable in all clinical situations - different postoperative outcomes of the variables being monitored would solve one of the biggest problems of tendon transfers after irreparable RN damage (19-24).Abrams in 1997. emphasized that the evaluation scheme of tendon transfer results in RN paralysis was missing (19). Standardization of results as a major problem in their work is presented by Zachary, Moberg and Nachemson, Deiler, Wiedeman, Chotigavanich, Omer,

Skoll (15, 20-24). Most authors use the Zachary scheme. The disadvantage of this most widely used Zachary scheme is that it does not define variables: for example, what is an incomplete (what value!) thumb extension, for which 10% of the maximum value of 100% is subtracted. The only parameter of the thumb score is the extension of the IP joint until the abduction values are not measured at all or included in the evaluation scheme. Zachary measures MCP finger extension II-V in a neutral wrist position(it is not functional position of wrist; most authors agree that functional position of wrist is 30^0 extension). Finally, it does not define „mild" and „severe" loss of finger flexion for which it subtracts 10% or 20%. The Tajima evaluation scheme defines variables as follows: „complete" (excellent result) versus „almost complete" movement (good result), which classifies the results into different groups without exact indicators.

The Thomsen and Rasmussen Zachary methods are considered „too rigid and simplistic" and note that too little attention is paid to functional results from the perspective of the subjective assessment of the patient (19).

However, they do not offer their own scheme and evaluate the results by the Zachary method. The main objection to the Zachary scheme is Chuinard's use of the „neutral position" (0 degrees) of the wrist when measuring active movements of the fingers and thumb (14). Furthermore, the excellent result of wrist movement for the Tajima ranges from 10 degrees of flexion to 10 degrees of extension. Due to the different possible combinations, it is often not possible to determine the final grade when the results of the commonly evaluated variables (wrist, finger and thumb movements) belong to different grades. For example, wrist movements are great, finger movements good and thumbs bad. The final grade in such an example cannot be determined at all based on the schemes available. Our Functional Scheme is based on the extent of movement of the wrist joints that present recovery of function after irreparable RN damage. They are included in the scheme of movements of the RD and UD of the wrist, which represent 18% of the upper extremity function, and were not included in the already existing evaluation schemes.

Based on the Functional own Evaluation Scheme, FCU tendon transfer resulted in an overall excellent result in one patient, a good result in 26 patients and a poor result in one patient. FCR tendon transfer resulted in a total excellent result in nine patients, a good result in 21 patients, a satisfactory result in 1 patient and a poor result in one patient. Statistically significant (p=0.004) better results were obtained by FCR tendon transfer.

Measured by the Zachary evaluation scheme, our total score in patients undergoing FCR tendon transfer was 91.20%. The total result in patients undergoing FCU tendon transfer was 81.20%. The total result of all operated patients was 86.20%. The F-ratio, which tests the significance of variance differences between patient groups operated by FCR and FCU tendon transfer, shows statistically significant differences (p = 0.022) in favor of better FCR TT results. The most important difference between the surgical procedure of FCR and FCU tendon transfer is in the donor tendon for finger extension. In our work, finger extension (II-V) had the greatest negative effect on the final functional total score in FCU tendon transfer, which is why an average of 11.80% was subtracted from the maximum score (100%) according to the Zachary scheme as opposed to 3.30% with FCR tendon transfer.

A qualified physiotherapist can help the patient understand a new way to control the hand, but only a patient can heal the wound and make an active hand movement. In tendon transfer planning, there is often a choice between a simple procedure, using synergistic muscles, and a more complicated procedure that requires retraining of non-synergistic muscles (26). We used for TT synergistic muscles. The Neumann-Pertecke scheme is a modified Zachary scheme according to which, based on the results achieved, the Zachary evaluation scheme is classified into 4 groups. The Neumann-Pertecke scheme presents how many excellent (I), good (II), satisfactory (III) and poor (IV) results we have received. In 33 patients (55%) an excellent and good result was achieved, in 22 patients (36.7%) a satisfactory result and in 5 patients (8.3%) a poor result was achieved. With Tajima scheme we could evaluate the results in 51 operated patients, the Chuinard scheme can evaluate the results in 41 patients and the Functional scheme in all 60 patients (Table 4). Therefore, it is not possible to evaluate the results in 19 patients (31.67%) according to the Chuinard scheme and 9 patients (15%) according to the Tajima scheme. With the evaluation schemes and the rating system offered by the Tajima and Chuinard schemes, only when evaluating the variables being evaluated that are at the same level, can we evaluate the patient with the final grade. With the Zachary scheme, we can evaluate each patient.

The disadvantages of the Zachary scheme are: too little attention is paid to results from a functional point of view, the use of a neutral wrist position when measuring active movements of the fingers and thumb, values of the variables being evaluated are defined as „mild or serious" loss of function, allowing the subjective interpretation of the examiner and obtaining different endpoints, in the same patient, in different examiners. In generally rare published works of tendon transfers for irreparable damage to the radial nerve, the authors try to present their scheme as most appropriate.

The results of tendon transfer in radial nerve palsy are presented by the authors of the evaluation schemes taking into account different variables, which makes it difficult to compare results (13-15). A further problem arises because of the non-definition of variables. Evaluation schemes differ significantly in the classification of results based on the measured active movements of the wrist, because the authors of the evaluation schemes classify the same values of results obtained by surgery in different groups of grades. Often, because of the various possible combinations, it is extremely difficult or not possible to determine the final overall grade because the results of the variables that are commonly evaluated belong to different grades. Therefore, the results of the patient in whom the postoperative results of all variables are the same can be classified. Its own Functional scheme is ap-

plicable to all clinical situations - different postoperative results of extension of wrist, fingers (II-V) and thumb, which makes other schemes inappropriate and unusable.

6. CONCLUSION

Forearm tendon transfer is a relevant method to compensate for the lost function of the wrist, fingers and thumb extensions as a result of irreparable damage to the radial nerve. A Functional evaluation scheme is simply applicable to the evaluation of all clinical cases of different postoperative outcome of the variables being evaluated. A functional evaluation scheme for tendon transfer results for radial nerve palsy enables the results to be compared. With a functional evaluation scheme, the final grade can be easily and precisely determined when the variables being evaluated belong to different grades, which was one of the biggest evaluation problems. The functional scheme is based on the functional movements of the joints being evaluated, and by including the movements of the RD and UD of the wrist, the extension of the MCP and the flexion of the IP joint of the thumb, the final evaluation becomes completely original. There are over 40 described tendon transfer methods for restauration of RN paralysis. The four tendon transfers are considered „better". Two of them are the subject of our work. FCR tendon transfer gave better functional results than FCU tendon transfer and we suggest them to be used in most clinical cases.

- **Declaration of patient consent**: The author certify that he obtained all patient consent forms.
- **Author's contribution**: R.K. gave substantial contribution to the conception or design of the work and in the acquisition, analysis and interpretation of data for the work. Author gave final approval of the version to be published and they agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
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