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Research Article

Assessment of Postoperative Functional Outcome Following Brachial Plexus Palsy: Development and Validation of the Ioannina Functional Scale

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Abstract

Aim: To create and validate a new assessment tool (Ioannina Functional Scale) for the postoperative evaluation of patients with

Methods: The study included 57 patients who suffering lesion to the brachial plexus and had undergone surgery at the Orthopaedic Clinic at the Faculty of Medicine of the University of Ioannina. All procedures were led by the same surgeon (M.D.V.) The collection of data for the research was carried out by reviewing patients' files, interviewing patients and retrieving information from their physiotherapists. In all cases, written consent was obtained from the patients. Previous assessments tools for evaluating upper extremity function like the Disabilities of the Arm, Shoulder and Hand (D.A.S.H.), the Pain Visual Analogue Scale (P.V.A.S.) and the International Classification of Functioning, Disability and Health (I.C.F.) constituted the baseline of our comparison. Multiple statistical methods were used to establish the validity and reliability of the I.F.S. Pearson's and Spearman's tests were used for validation, Cronbach's alpha procedure for reliability, and Shapiro-Wilk for normality.

Results: Mean value of index for the I.F.S. was 49.81. A positive and very strong linear correlation between I.F.S. and D.A.S.H. indexes was documented. Distribution of the I.F.S. was found to be normal. Correlation between I.F.S. and P.V.A.S. were statistically significant with $p = 0.000$.

Conclusion: Based on the reliability and validity tests carried out in the present study, the Ioannina Functional Scale was found to be a useful assessment tool for evaluating the postoperative progress in patients with brachial plexus injury.

Keywords: Brachial Plexus Injury; Brachial Plexus Palsy; Clinical Assessment Tools; Clinimetrics

Abbreviations

I.F.S: Ioannina Functional Scale; D.A.S.H: Disabilities of the Arm, Shoulder and Hand; P.V.A.S.: Pain Visual Analogue Scale; I.C.F.: International Classification of Functioning, Disability and Health

Introduction

Brachial plexus palsy is associated with significant loss of upper extremity function in usually young and otherwise healthy patients. The functional impairment results in prolonged rehabilitation programs in the vast majority of patients and in many cases to permanent disability.

The postoperative course differs among patients with brachial plexus palsy depending on the severity of the paralysis, and the treatment methods. Adequate assessment of such patients is of crucial importance for both the rehabilitation team resulting in optimal improvement of upper extremity functionality and the surgeon in order to plan future operations that could further improve this functionality. Precise evaluation of patient's postoperative course is a useful tool in mapping of mobility and sensory possibilities that arise during the reanimation phase which allows for the readjustment and amendment of the therapeutic scheme. The recording and verification of the progress of rehabilitation programs through clinical scores increases the feedback between patient and treating clinicians and aids in monitoring patient's progress and provide documented information as to the effectiveness of current treatment.

Till recently, the assessment of patients with brachial plexus palsy targeted the mapping of mobility and sensibility of the upper extremity in relation to the degree of nerve regeneration. The assessment tools reported in the published literature are based on the evaluation of range of motion, muscular strength and sensory changes [1-3]. However, during the last few years an increasing need for evaluation of further parameters such as functionality and patients' quality of life has arisen [3-5].

Aim of the Study

The aim of this study is the creation of a simple, easily applicable and quick-to-use assessment tool for the evaluation of patients with brachial plexus palsy that can be used to map and link the postoperative clinical picture of patients' mobility, sensibility and functionality. The Ioannina Functional Scale (I.F.S.) was designed in order to record the postoperative muscular and sensory functionality of patients with brachial plexus palsy in order to assess the course of the rehabilitation program.

Materials and Methods

Patients

Fifty seven patients who had suffered a global brachial plexus lesion were initially considered eligible to participate in the present study. In all cases, written informed consent was obtained from the patients. From the 57 patients initially included in the study, 17 patients were excluded due to lack of compliance to the physiotherapy program. Eventually, 40 patients participated in the present study.

The mean follow up time was 3.35 years (+/- 1.1). The median age of patients at the time of operation was 23 years (range 15 - 35 years). The vast majority of the patients were males (36 patients). The denervation period was 1 - 3 months in 27.5%, 4 - 6 months in 57.5% and more than 6 months in 15% of our sample population. In 72.5% of the sample, avulsion of nerve root(s) was present (3 patients with complete avulsion of allnerve roots, 10 with avulsion of four roots, 8 with avulsion of three roots, 6 with avulsion of two roots and 2 patients with avulsion of one nerve root).

Surgical technique

All patients were operated at the Department of Orthopaedic Surgery of the University Hospital of Ioannina. All procedures were performed by the same surgeon (M.D.V.). Exploration of the brachial plexus was performed and depending on whether the donor nerve was part of the brachial plexus or not, the neurotisation was categorised as intraplexus or extraplexus, where:

- Intraplexus neurotisation is neurotisation using donor nerves harvested from within the brachial plexus (C5 and C6 roots).
- Extraplexus neurotisation is neurotisation using donor nerves harvested from outside the brachial plexus (the spinal accessory nerve, the phrenic nerve, the cervical plexus motor donor, the intercostal nerves and the contralateral C7 root).

Neurotisation of the suprascapular nerve was performed in all patients since it is considered as one of the primary targets in brachial plexus reconstruction along with musculocutaneous nerve. Therefore, both these nerves were reconstructed in all patients. For the suprascapular nerve reconstruction, the spinal accessory nerve was used as donor nerve in 80% of patients, the C5 root was used in 10%, the branch of the cervical plexus was used in 5% and the phrenic nerve was used in the remaining 5%. Neurotisation of the axillary nerve was carried out in 60% of the patients. The C5 root was used as donor in 65%, the phrenic nerve in 12.5% and a branch of the cervical plexus was used in 17.5%. For elbow flexion, neurotisation of the musculocutaneous nerve was performed in all patients included in the study. The phrenic nerve was used in 45%, branches of the C5 root in 32%, the ulnar nerve in 15% and the spinal accessory nerve in 8%. Neurotisation of the median nerve was carried out in 70% of our sample. C5 root was used in 60%, and intercostal nerves was used as donor in 40%. Generally, intraplexus neurotisation was used in 32.5% of our patients and extraplexus neurotisation in 77.5%.

Postoperative assessment

At 6 weeks postoperatively, the patients started physiotherapy and electrotherapy protocol. All patients were evaluated at 4 month intervals till the final evaluation that was performed at 24 months postoperatively. The evaluation of patients was performed with a novel functional scale, introduced by our institution (Ioannina Functional Scale). Moreover, all patients were also evaluated with the International Classification of Functioning, Disability and Health (ICF) the Disabilities of the Arm, Shoulder and Hand (DASH) [6] and the Pain Visual Analogue Scale (PVAS) [7] assessment tools in order to test the credibility and external validity of the Ioannina Functional Scale. All assessment tools were used in Greek language.

Description of the Ioannina Functional Scale (I.F.S.)

The I.F.S. is divided into four sections describing:

- A: joint's range of motion,
- B: muscular strength,
- C: functionality and
- D: protective sensibility.

The two first sections (A and B) record the mobility and muscular strength of the injured structures and describe the course of rehabilitation. More precisely:

- A: Section for the recording of range of motion of the upper extremity. Section A is divided into subsections:
- A1: Recording the passive range of motion.

An extremity's passive range of motion provides us with information about the condition of the joint structures after the

Functional assessment scale for brachial plexus injuries

***A*: Range of motion of the upper extremity**

A.1 Passive Range of Motion (cycle the correct answer)					
A.1.1. Shoulder					
Flexion	0^0	0^0-30^0	0^0-60^0	0^0- 90^0	0^0- 180^0
Extension	0^0			0^0-30^0	
Abduction	0^0	0^0-30^0	0^0-60^0	0^0-90^0	0^0- 180^0
Adduction	0^0				
External Rotation	0^0	0^0-30^0	0^0-60^0	0^0-90^0	
Internal Rotation	0^0		0^0-60^0	0^0-100^0	
A1.2. **Elbow**					
Flexion	0^0	0^0-30^0	0^0-60^0	0^0-90^0	0^0-140^0
Extension	0^0				
A1.3. **Forearm**					
Pronation	0^0		0^0-20^0	0^0-40^0	0^0-80^0
Supination	0^0		0^0-20^0	0^0-40^0	0^0-80^0
A1.4. **Wrist**					
Flexion	0^0		0^0-30^0	0^0-60^0	
Extension	0^0		0^0-30^0	0^0-60^0	
A1.5. Wrist Arthrodesis	Yes		No		
A1.6. Hand					
Gripping	Yes	No			
A.2 Active Range of Motion (cycle the correct answer)					
A.2.1. Shoulder					
Flexion	0^0	0^0-30^0	0^0-60^0	0^0- 90^0	>90^0
Extension	0^0			0^0-30^0	
Abduction	0^0	0^0-30^0	0^0-60^0	0^0-90^0	>90^0
Adduction	0^0				
External Rotation	0^0	0^0-10^0	0^0-30^0	>30^0	
Internal Rotation	0^0		0^0-60^0		
A.2.2. Elbow					
Flexion	0^0	0^0-30^0	0^0-60^0	0^0-90^0	0^0-140^0
Extension	0^0				
A1.3. **Forearm**					
Pronation	0^0		0^0-20^0	0^0-40^0	0^0-80^0
Supination	0^0		0^0-20^0	0^0-40^0	0^0-80^0
A1.4.**Wrist**					
Flexion	0^0		0^0-30^0	0^0-60^0	
Extension	0^0		0^0-30^0	0^0-60^0	
A1.5.**Hand**					
Gripping	Yes		No		

B. Muscle strength		**B.M.R.C Grading System Expanded with (+) and (-)**
B.1 Shoulder		
Muscle Groups for Shoulder Girdle Elevation		
	Rhomboids	
	Trapezius	

Muscle Groups for Shoulder Abduction		
	Deltoid	
	Supraspinatus	
	Serratus Anterior	
Muscle Groups for Shoulder External Rotation		
	Infraspinatous	
	Teres Minor	
Muscle Groups for Shoulder Flexion		
	Anterior Deltoid	
	Pectoralis major	
Muscle Groups for Adduction and Internal Rotation		
	Latissimus Dorsi	
	Pectoralis major	
B2. Elbow		
Muscle Groups for Elbow Flexion		
B2.1	Bicep	
B2.2	Brachioradialis	
Muscle Groups for Elbow Extension		
B2.3	Triceps	
B.3 Wrist		
B3.1.	Wrist Extensors (E.C. Radialis B./L. –E.C. Ulnaris)	
B3.2	Pronator	
B.4 Hand		
B4.1	Fingers Flexion	
B4.2	Fingers Extension	

C. Ability to Execute Everyday Activities.		**No Difficulty**	**Mild Difficulty**	**Moderate Difficulty**	**Severe Difficulty**	**Unable**
C1	Lifting large object (such as a bag)	0	1	2	3	4
C2	Carrying large object (such as a bag or a chair)	0	1	2	3	4
C3	Open a door	0	1	2	3	4
C4	Close a door	0	1	2	3	4
C5	Picking up small objects	0	1	2	3	4
C6	Push small objects	0	1	2	3	4
C7	Table/office cleanness in a circular motion	0	1	2	3	4

D. Protective Sensibility and Pain		**No Difficulty**	**Mild Difficulty**	**Moderate Difficulty**	**Severe Difficulty**	**Unable**
D1	Sensory function of movement	0	1	2	3	4
D2	Sensory functions of sensing cold and heat	0	1	2	3	4
D3	Sensitivity to a noxious stimulus	0	1	2	3	4
D4	Pain	0	1	2	3	4

Table 1: Ioannina functional scale.

immobilisation or the possible restrictions that might occur due to fractures or scar tissue from the initial trauma.

- A2: Recording the active range of motion.

  An extremity's active range of motion shows the degree of functionality that can be achieved.

- B. Section for the recording of muscular strength of the upper extremity with the British Medical Research Council (BMRC) Grading System [8] expanded further with intermediate grades of (+) and (–) (i.e. M2, M2+, M3-, M3, M3+) [9,10].

  The measuring of muscular strength of every affected muscle separately, gives us a specific clinical picture of each individual patient.

- C. Section for the recording of ability to execute everyday activities.

  Refers to a list of basic activities involving the injured limb i.e. carrying of a bag or a chair. The degree of difficulty in executing these tasks is recorded.

- D. Section for the recording of protective sensibility and pain.

  Recording in a chart of protective sensibility such as the feeling of hot/cold, proprioception and pain, as subjectively perceived by the patient.

Statistical procedures

The DASH, ISF and IFS index were calculated. The IFS index was calculated with the same mathematical type as the DASH index (Dash Disability Symptom Score = [(sum of n responses) - 1] x 25, where n is equal to the number of completed responses). Were coded the categories of the ten variables, transformed them into a 100-grade scale and then calculated the I.F.S. The index values nearing 100 correspond to complete difficulty while the values nearing 0 constitute no difficulty at all. The new functional scale was evaluated for its internal and external validity.

In order to evaluate the normal distribution of our sample for the DASH and IFS questionnaires, we used the Kolmogorov-Smirnov and Shapiro-Wilk tests. The Shapiro-Wilk test is recommended for small samples, in which values greater or lesser than 1.96 are sufficient to establish normality of the data.

To check the reliability of IFS and DASH questionnaires, we used the Cronbach's alpha coefficient for internal consistency. For this procedure, values of between 0.70 and 0.90 are considered satisfactory.

For the external validation of the IFS, we correlated the IFS scale with the DASH, the PVAS and the ICF using the Pearson's and Spearman's correlations. P values <0.05 were considered statistically significant; all p values were two-tailed. All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS 22.0, Chicago, IL, USA).

Results and Discussion

The disability index of the D.A.S.H. ranged from 8.33 to 94.17 with the mean value being 56.25 +/- 24.12, which corresponds to a medium level of disability in the sample population. The disability index of the I.F.S. ranged from 5 to 97.50 and the mean value of the index was 49.81 +/- 27.24. This also corresponds to a medium disability level in the sample population in accordance to the D.A.S.H. score. The distribution of the I.F.S. and D.A.S.H. indexes respectively is shown in figure 1. The mean value of P.V.A.S. was 4.20 +/- 2.75.

In order to examine the normality of our sample population for the D.A.S.H. questionnaire, we used the Kolmogorov-Smirnov and

Figure 1

Shapiro-Wilk tests. We noted that Sign. = 0.20 for the Kolmogorov-Smirnov test and Sign. = 0.196 for the Shapiro-Wilk test. Both p values were < 0.05, which shows statistical significance indicating a normal sample distribution. In concordance to the previous results, a normal sample distribution was also seen when the I.F.S. questionnaire was used (Sign. = 0.20 with the Kolmogorov-Smirnov test and Sign. = 0.176 withthe Shapiro-Wilk test).

The estimation of the reliability of the I.F.S. was checked with the coefficient of the internal consistency Cronbach's alpha. The alpha coefficient for all participants (N = 40) for all ten questions in the I.F.S. is 0.964, suggesting that the items have relatively high internal consistency.

D.A.S.H. index and P.V.A.S.

As expected, a strongly positive and statistically significant correlation was noted between the DASH and PVAS scores with p < 0.001.

I.F.S. Variable		I.C.F./ D.A.S.H. Variables		Correlation Coefficient Spearman	Statistically Significant
I.F.S. - C1	Lifting large object (such as a bag)	I.C.F._d430	Lifting and carrying object	0,950	√
I.F.S. - C2	Carrying large object (such as a bag or a chair)	I.C.F._d4302	Carrying in the arms	0,963	√
I.F.S. - D1	Sensory function of movement	I.C.F._b260	Proprioceptive sensory function	0.966	√
I.F.S. - D2	Sensory functions of sensing cold and heat	I.C.F._b2700	Sensory functions of sensing cold and heat	0.966	√
I.F.S. - D3	Sensitivity to a noxious stimulus	I.C.F._b2703	Sensory functions of sensing painful or uncomfortable sensations	0.966	√
I.F.S. - D4	Pain	I.C.F._b280	Sensation of pain	0.978	√
I.F.S. - C3	Open a door	D.A.S.H.5	Push open a heavy door	0,941	√
I.F.S. - D4	Pain	D.A.S.H.24	Arm, shoulder or hand pain.	0.825	√
I.F.S. - D4	Pain	VAS	Pain Scale	0.912	√

Table 2

External validity - Correlation of the I.F.S. index with other scores

Using the Spearman's correlation coefficient, a strongly positive and statistically significant correlation was seen between the IFS and the PVAS, with p values < 0.001 (Table 2). In addition, a positive and very strong linear correlation between the I.F.S. index and the D.A.S.H. index was seen (p < 0.001) (Table 2). All comparisons carried out between the variables of the I.F.S. and relevant variables of the I.C.F. exhibited a statistically significant correlation (Table 2).

The above results led us to the conclusion that the I.F.S. index is equally capable of indicating the functional disability while making use of fewer questions than the D.A.S.H. for the patients in our sample.

Conclusion

The assessment of the postoperative course in patients with brachial plexus palsy is of crucial importance by evaluating the sensory motor improvement during the reinnervation phase. Moreover, the assessment of functionality provides valuable information for the readjustment and amendment of the therapeutic protocol, the motivation and feedback to patient and therapist.In general, patients with injury to the brachial plexus face loss of active mobility, weakness of the upper limb and altered sensibility [11]. In this particular group of patients, rehabilitation is considered a success when the patient regains "useful" functionality. "Useful" rehabilitation is defined as partial motor control of the shoulder, strong elbow flexion and partial motor control of the hand. Millesi notes that 72% of patients regain "useful" functionality following neurolysis and 70% following nerve grafting [12] Chuang DCC (2010) reports that successful rehabilitation of patients following nerve grafting is considered to be achieved when the patient exhibits a 180 degree shoulder flexion, M4 muscle strength, M4 to M4+ elbow flexion and extension, M3- to M3+ finger flexion and extension and M2 (or less) hand intrinsic muscles movement [13]. In the case of avulsion of nerve roots and where neurotisation has been performed, successful rehabilitation is considered to be achieved when the patient exhibits a 60 degree shoulder abduction, M4 elbow flexion and M2-

M4 finger flexion. Extension of elbow and fingers can be achieved at a later stage with a free functional muscle transplant.

Knowing that the harmonic movement of the upper limb is no longer present following injury, the need for an assessment tool designed specifically to map the functional impairment of this particular patient group, is considered necessary. Till now, the assessment of postoperative course of patients with brachial plexus palsy, was based on tools such as the P.V.A.S and the D.A.S.H [12,14-16]. Moreover, the I.C.F. is a useful framework for the classification of the effect on an individual after brachial plexus injury, where the impact of the injury on somatic structures and their function is classified according to the resulting restrictions and activity of the patient [12,17]. These tools are internationally recognised for their validity and when combined they can evaluate pain levels and functional rehabilitation of these patients.

However, the inflexible condition under which the D.A.S.H. can be used to assess the disability index, i.e. the answering of at least 27 of the 30 questions necessitated the development of a new assessment tool. In particular, during the patient interviews that we carried out, it became apparent that there are more than only three questions that cannot be answered by this particular group of patients in the D.A.S.H. questionnaire. There are also questions of which we know beforehand cannot be answered due to the inability of these patients to carry out these tasks. In general, at least seven questions in the D.A.S.H. questionnaire cannot be answered by patients with brachial plexus palsy, thus more than the three allowed for in the design of the D.A.S.H.

Being more specific ,questions like 'Open a tight or new jar", "Write" and "Turn a key" all assume a harmonic movement of the hand(supination/pronation - extension of fingers and thumb) and tasks such as "Change a light bulb overhead", "Wash or blow dry your hair", "Wash your back" and "Put on a pullover sweater" assume an ability to flex or abduct the shoulder more than 120 degrees, excellent flexion of the elbow and the concurrent harmonic movement of the wrist using supination and pronation. These are all movements which patients in postoperative useful rehabilitation of the brachial plexus cannot carry out. Since they are obliged to answer all but three, the index would not be representing the actual 'useful' recovery of patients.

Moreover, the psychological pressure on the patient, caused by asking questions that cannot reasonably be answered, is potentially enormous. Depending on personality and expectations for patient recovery, the perceived extent of loss as charted, could trigger and increase the emotional trauma of the initial injury and furthermore might interfere with their discipline or willingness to continue rehabilitation. The whole process of rehabilitation may seem pointless.

On the other hand, although variables of the I.C.F. relate to the weaknesses experienced by patients in the postoperative progress, i.e. lack of active movement, weakness of the upper extremity and changes in sensibility, the tool is descriptive and has not been designed to measure degree of disability.

All the above concerns necessitated the development of a new assessment tool, The Ioannina Functional Score. Our score showed a positive and very strong linear correlation with the D.A.S.H. index, indicating equal ability in mapping the functional disability of patients with brachial plexus palsy, while using fewer questions than the D.A.S.H. Moreover, in our study we used the relevant variables of the I.C.F. to assess the I.F.S. All comparisons carried out between the variables of the I.F.S. and relevant variables of the I.C.F. exhibited a statistically significant correlation. The advantage of I.F.S. over I.C.F. is the possibility to obtain an index [18-20].

In conclusion, based on the statistical analyses carried out in the present study, the Ioannina Functional Scale is a suitable tool for assessment of postoperative progress in patients with brachial plexus injury. It is simple, reliable and applicable to all brachial plexus patients. It correlates functional outcome with objective clinical measurements i.e. muscle strength and ROM and it provides clinicians with a comparable index.

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