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Validity and Reliability of Prognosis Brachial Plexus Injury Score for Traumatic Brachial Plexus Injury

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Background: Brachial plexus injury (BPI) is a peripheral nerve injury that results in severe functional impairment and disability. Even after prompt treatment, predicting the prognosis of BPI is not easy as it involves various factors. An objective and valid scoring system would aid clinicians in informing families and anticipating problems related to the recovery of BPI. Prognosis BPI (PRO-BPI) score, a new prognostic score to predict the outcome of traumatic BPI (TBPI), was developed in 2019 by Suroto and Rahman. This study aimed to evaluate its validity and reliability.

Methods: Retrospective cohort analysis was conducted for 111 BPI patients. A serial assessment of Disabilities of the Arm, Shoulder and Hand (DASH) score and PRO-BPI score was done. Validity analysis was done by assessing Spearman correlations between PRO-BPI score and other scoring systems (DASH, Michigan hand outcomes, and 36-item short form survey score [SF-36]). Internal structure consistency using Cronbach's alpha and test-retest reliability were measured for reliability analyses. A *p*-value was considered significant if < 0.05.

Results: A total of 96 male and 15 female patients were included in our study with a mean age of 27.9 ± 10.6 years. Most of the patients (56.75%) had a poor prognosis based on the scoring system (average, 14.38 ± 3.98). Major contributors of this low score were the persistent pain (score 1 in 57.7% patients) and initial pain scale score (score 1 in 31.5% patients). Validity test showed that 6 parameters were all valid ($p < 0.01$). Reliability testing was done using Cronbach's alpha and found acceptable internal consistency ($\alpha = 0.767$). Test-retest reliability was high. Moderate correlations were observed between the measures.

Conclusions: PRO-BPI score is a valid and reliable scoring system in predicting the prognosis of TBPI.

Keywords: *Brachial plexus, Nervous system trauma, Validity and reliability, Prognostic factor*

Brachial plexus injury (BPI) is one of the most disabling peripheral nerve diseases. If left untreated, it will cause impairment on the upper extremity.[1] Moreover, BPI commonly occurs in productive ages, which may lead to a colossal socioeconomic burden on the patient.[2,3] In the United States, it is estimated that 0.6–3.9 per 100,000 person-years is affected by BPI. In our center, there are approximately 35 cases of BPI per year, which is commonly caused by motor vehicle accidents in patients aged 21–30 years.[2] Treatment for BPI keeps evolving alongside peripheral nerve reconstruction techniques. Some of the established modalities for surgeons are neurolysis, nerve repair, nerve grafting, and nerve transfer. The goal of the therapy is to regain clinical function and improve the quality of life. Despite advancements in the treatment of

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BPI, the prognosis of BPI in patients remains hard to predict although it is crucial to anticipate necessary follow-up treatment and/or to even up doctor-patient expectations on the outcome of the disease.[4]

The prognosis for BPI is determined by various factors. One of the objective ways to predict a patient's prognosis is using a scoring system. To our knowledge, prognosis BPI (PRO-BPI) score developed by Suroto and Rahman[5] is the only prognosis scoring system available for traumatic BPI (TBPI). This scoring system predicts the postoperative outcome of TBPI based on the mode of injury (MOI), initial pain scale score, persistent pain, level of injury, time to surgery, and initial electromyography (EMG) result. A score of less than 15 translates into a good functional prognosis and a poor prognosis for a score of more than or equal to 15.[5] The aim of this study was to evaluate the validity and reliability of the PRO-BPI score.

METHODS

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of General Academic Hospital, Surabaya, Indonesia (No. 0153/107/3/VIII/2020). The written informed consent was obtained from all patients.

Analytic observational study with retrospective cohort design was conducted at Dr Soetomo General Academic Hospital between July 2020 and July 2021. The inclusion criteria were patients with BPI who (1) underwent surgery between January 2012 and December 2018 and (2) consented to be included in this study. Patients with the following conditions were excluded from the study: (1) birth BPI, (2) neurological deficit due to central nervous system impairment, (3) underlying vascular etiology, (4) upper extremity amputation, (5) delayed union or nonunion, which causes persistent pain, and (6) incomplete data.

Validity test was conducted using the Spearman correlation test between PRO-BPI score and the difference in initial Disabilities of the Arm, Shoulder and Hand (DASH) score, Michigan hand outcomes, and 36-item short form survey score (SF-36) at the time of the study. A p-value of < 0.05 was considered significant. Reliability test was done using test-retest method for DASH score while internal consistency was tested using Cronbach's Alpha.[6]

RESULTS

A total of 136 patients were included as the study population. However, 13 patients were excluded due to the presence of other comorbidities that would influence the data (10 cases of stroke and 3 cases of upper extremity malunion) and another 12 patients were excluded due to incomplete data. Amongst the 111 included patients, 86.5% (n = 96) were men with an average age of 27.9 ± 10.6 years. The PRO-BPI scores are described in detail in Table 1. More than half of the patients showed poor prognosis (56.75% of the patients with scores 15–20). The major contributors of these low scores was persistent pain (score 1 in 57.7% patients) and initial pain scale score (score 1 in 31.5% patients).

In this study, aside from collecting and applying the PRO-BPI scores, we also tabulated patient's DASH score. Comparing the interpretation of both scores, PRO-BPI score showed a poor functional prognosis, which was in concordance with the poor DASH score, indicating a severely disabled extremity. Both scoring systems produced a similar conclusion despite using different parameters (Table 2). Moreover, different surgical methods did not seem to provide significant difference in DASH score and SF-36. For the PRO-BPI score, free functional muscle transfer surgery method resulted in a higher average score than other surgery methods (15.6 ± 3.45) but the difference was not statistically significant ($p > 0.05$).

Validity testing using spearman correlation showed validity for all parameters compared to the DASH score ($p < 0.05$) (Table 3). Reliability testing was done using Cronbach's Alpha and showed acceptable internal consistency ($\alpha = 0.767$). We found a significant correlation between visual analog scale (VAS) score 4–6, level of injury C5-6, level of injury C7-Th1, and level of injury C5-Th1 ($p < 0.05$). There was a strongly positive correlation for traction injury ($r = 0.45$), C5-Th1 level of injury ($r = 0.52$), and EMG score 3 ($r = 0.42$), which means that the availability of these variables (for positive correlation coefficient and vice versa) usually would produce a high PRO-BPI score (Table 4).

DISCUSSION

The PRO-BPI score was developed as a systematic tool or instrument to predict the prognosis of TBPI at the time of the original author's writing as there had been no tools to predict the prognosis of TBPI. This scoring system was built to aid in the decision-making on the appropriate treatment of TBPI and to enable physicians to systematically predict the prognosis, consequently managing the patient's expectation. In creating this scoring system, all known factors affecting outcome of TBPI were noted from

Table 1. The PRO-BPI Score

Scoring criteria	Interpretation	Quantity	Mean ± SD
Mode of injury (V1)			2.54 ± 0.58
Score 1	Penetrating injury	5 (4.5)	
Score 2	Compression injury	41 (36.9)	
Score 3	Traction injury	65 (58.6)	
Persistent pain (V2)			1.42 ± 0.50
Score 1	Subsides within less than 6 months	64 (57.7)	
Score 2	Persistent for more than 6 months	47 (42.3)	
Initial pain scale (V3)			1.90 ± 0.73
Score 1	VAS 1–3	35 (31.5)	
Score 2	VAS 4–6	52 (46.8)	
Score 3	VAS 7–10	24 (21.6)	
Level of injury (V4)			4.23 ± 1.92
Score1	C5-6 post-ganglion	19 (17.1)	
Score 2	C5-7 post-ganglion	10 (9.0)	
Score 3	C8-Th1 post-ganglion	6 (5.4)	
Score 4	C5-Th1 post-ganglion	11 (9.9)	
Score 5	C5-6 post-ganglion, C7-Th1 pre-ganglion	22 (19.8)	
Score 6	C5-Th1 pre-ganglion	43 (38.7)	
Time to surgery (V5)			2.14 ± 0.77
Score 1	Early (< 6 mo)	26 (23.4)	
Score 2	Delayed (6–12 mo)	43 (38.7)	
Score 3	Late (> 12 mo)	42 (37.8)	
Initial EMG (V6)			2.14 ± 0.67
Score 1	All or part of muscles have partial denervation (FP +, PSW +, some MUP [–])	18 (16.2)	
Score 2	Some muscles have partial denervation and the others total denervation (FP +, PSW +, Some MUP [–]).	59 (53.2)	
Score 3	Nearly all (≥ 80%) or all muscles have total denervation (FP +, PSW +, MUP [–]).	34 (30.6)	
Total score			14.38 ± 3.98
Score 5–14		48 (43.24)	
Score 15–20		63 (56.75)	

Values are presented as number (%) unless otherwise indicated.
PRO-BPI: prognosis brachial plexus injury, SD: standard deviation, VAS: visual analog scale, EMG: electromyography, FP: fibrillation potentials, PSW: positive sharp waves, MUP: motor unit potentials.

the samples. These factors were then statistically analyzed to test whether they were able to predict DASH score of the same patient.[5]

The DASH scoring system is one of the most commonly used scoring systems to measure the severity of upper limb pathology and the improvement after treatment.[7]

Table 2. Comparison between PRO-BPI Score, DASH Score, and SF-36

Score	External neurolysis	FFMT	Nerve grafting	Nerve transfer	Overall score	Interpretation
PRO-BPI score	12.9 ± 4.18	15.6 ± 3.45	13.1 ± 3.79	12 ± 4.14	16.41 ± 3.98	Poor functional prognosis (> 15)
DASH score	18.94 ± 8.52	17.72 ± 10.4	15.99 ± 7.04	16.3 ± 10.4	47.51 ± 23.26	Poor extremity disability (> 35)
SF-36	31.9 ± 8.5	32.32 ± 10.24	32.78 ± 14.46	34.42 ± 10.81	70.12 ± 13.89	Disability exists

Values are presented as mean ± standard deviation.
PRO-BPI: prognosis brachial plexus injury, DASH: Disabilities of the Arm, Shoulder and Hand, SF-36: 36-item short form survey score, FFMT: free functional muscle transfer.

Table 3. Validity Test Result of Scoring Criteria

Parameter	*p*-value (two-tailed)	Conclusion
Mode of injury	< 0.001	Valid
Initial pain scale	< 0.001	Valid
Persistent pain	< 0.001	Valid
Level of injury	< 0.001	Valid
Time to surgery	< 0.001	Valid
Initial EMG	< 0.001	Valid

EMG: electromyography.

A DASH score of more than or equal to 40 translates into debilitating disability of the upper extremity and vice versa.[8] Meanwhile, SF-36 is also a commonly used scoring system used to measure overall health-related quality of life.[9] As BPI affects mainly the upper extremity and the original study used DASH as a measuring system, we also used DASH to compare the outcome of BPI with PRO-BPI score. Moreover, to analyze the patient's overall health, SF-36 was used to give an overview of the patient's condition.

Aside from the factors included in PRO-BPI score, other studies assessing the prognosis of BPI also noted that age was a determining factor.[10] The rationale behind "age" is because older people's nerve regeneration is slower than younger patient's. Despite this rationale, the study by Suroto and Rahman[5] found that the traumatic brachial plexus injury (TBPI) postoperative outcome of younger patients did not differ significantly from that of older patients. This is because the study found younger patients tended to have a worse MOI, which offset the poor regeneration capability of older patients.[5] Moreover, a systematic review by Martin et al.[11] analyzed various papers studying BPI and found from combined data of 2,204 patients that most BPI patients were less than 60 years old as in the case of the current study (age range, 17–60 years), making it hard to affirm or refute the influence of age on BPI outcome.[11]

An interesting finding is that all patients with high PRO-BPI scores had bad EMG result as well. Of the 56 patients with high BPI scores, 26 (46.5%) had EMG scores of 1 and 30 (53.5%) had EMG scores of 2, i.e., none had a near to normal EMG result. EMG result for predicting prognosis of BPI had been studied previously and was found to be able to predict the prognosis well. Impastato et al.[12] found that patients with no evidence of voluntary recruitment had no muscle improvement. Meanwhile, patients with discrete recruitment had muscle improvement in 20% of samples. The difference was statistically significant.

Other metrics, which are found to have high correlation with total BPI score, were traction injury and VAS 4–6. For traction injuries, of the 56 patients with high BPI, 51 (91%) were with MOI of traction injury and this was much higher than the overall percentage of the total samples with traction injury (58.6%). Previous studies did not compare different MOI but mostly only stated the number of patients who had BPI by motor vehicle accidents.[11,13] Theoretically, the severity of the injury and also the associated soft-tissue damage caused by motor vehicle accidents (most common cause of traction injuries) cause worse prognosis than the other MOI. Further studies are needed to ascertain this hypothesis.

With regard to VAS scores, of the 56 patients with high BPI scores, 34 (60.7%) had initial pain scale scores of 4–6 and 21 (37.5%) had initial pain scale scores of 7–10. The distribution was similar to the general sample distribution of VAS scores. Instead, interestingly, only 1 patient (1.7%) with VAS 1–3 had a high PRO-BPI score, which differed quite highly from the general sample distribution of 21.6%. We believe that this high correlation is better interpreted the other way around, i.e., better prognosis on patients with low VAS scores. To the best of our knowledge, there are no other studies that compared the initial pain scale score and surgical outcome of TBPI to compare this result.

Limitations of this study include the fact that we did not consider the time from surgery to assessment, type of

Table 4. Questionnaire Content Correlation Test

No.	Criteria	Assessment	*r*	*p*-value
1	Mode of injury	Penetrating injury	–0.2	0.179
		Compression injury (direct)	–0.38	0.582
		Traction injury (indirect)	0.45	0.672
2	Initial pain scale	VAS 1–3	–0.52	0.129
		VAS 4–6	0.23	0.045
		VAS 7–10	0.31	0.078
3	Persistent pain	Subsides within less than 6 months	–0.46	0.121
		Persistent for more than 6 months	0.46	0.131
4	Level of injury	C5-6 post-ganglion	–0.52	0.082
		C5-7 post-ganglion	0.22	0.679
		C8-Th1 post-ganglion	0.12	0.502
		C5-Th1 post-ganglion	0.06	0.150
		C5-6 post-ganglion, C7-Th1 pre-ganglion	0.12	0.019
		C5-Th1 pre-ganglion	0.52	0.007
5	Time to surgery	Early (< 6 mo)	–0.26	0.282
		Delayed (6–12 mo)	–0.1	0.116
		Late (> 12 mo)	0.33	0.250
6	Initial EMG (presence of active unit motor, appearance of initial potential, and presence of potential fibrillation)	All or part of muscles have partial denervation (FP +, PSW +, some MUP [–])	–0.47	0.130
		Some muscles have partial denervation and the others total denervation (FP +, PSW +, some MUP [–])	–0.05	0.122
		Nearly all (≥ 80%) or all muscles have total denervation (FP +, PSW +, MUP [–])	0.42	0.052

VAS: visual analog scale, EMG: electromyography, FP: fibrillation potentials, PSW: positive sharp waves, MUP: motor unit potentials.

operation was also not assessed, and we did not assess the pain outcome but only postoperative functional outcome of the samples. Despite these limitations, overall, this study confirmed the validity of the PRO-BPI score, offering initial evidence for more detailed studies and widespread use of the score. Based on the results of the current study, PRO-BPI score is a valid and reliable scoring system in predicting the prognosis of TBPI. Patients with high PRO-BPI scores need to be treated more aggressively.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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