Original Research Article

Spasticity Outcome Tools in Traumatic Complete Spinal Cord Injury

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Abstract

Objective: To evaluate spasticity in patients of complete motor complete spinal cord injury using M.A.S ,SCATS and PSFS tools of spasticity and assessing their correlation. **Design**: Observational cross-sectional study. **Setting**: In-patient rehabilitation ward. **Participants**: 50 individuals of chronic (≥ 1 year trauma) motor complete SCI were classified into mild (n=16), moderate (n=11), and severe (n=23) spastic groups; based on their lower limb extensor muscle group spasticity score using a Modified Ashworth Scale (M.A.S), Spinal cord assessment tool for spastic reflexes(SCATS) and Penn spasm frequency scale (PSFS). **Main Outcome Measures:** The proportion of cases in mild, moderate, severe spastic groups, mean MAS score, mean SCATS Score and PSFS Score were evaluated and were compared between the groups with different grades of spasticity. **Results**: The mean M.A.S score among the study group was 3.71±1.60. The mean SCAT ankle clonus score, flexor spasm score and extensor spasm score were 1.55±1.05, 1.36±0.81 and 1.22±0.76 respectively (P<0.001S).The mean PSFS (frequency) score and mean PSFS (severity) score was 1.78±0.84 and 1.56±0.70 respectively(P<0.001S). All the three spasticity outcome tools were found to be significantly associated with the type of spasticity (P≤0.001).A significant positive correlation was observed between M.A.S score and the mean PSFS (FREQ; r = 0.856) score and PSFS (SEV; r = 0.818) score and the mean SCAT score(r=0.913). **Conclusion**: All three spasticity outcome tools M.A.S, PSFS and SCATS are acceptable as well as feasible, inherit good clinical utility and correlate significantly with the severity of spasticity. Significant correlations were observed between SCATS score and PSFS score with the M.A.S score. No single outcome measure can reflect the multidimensional nature of spasticity; hence a battery of tests should be applied to measure spasticity to plan antispasmodic treatment in such patients.

Keywords: Spinal cord injury, Spasticity, Modified Ashworth score, Spinal cord assessment tool for spastic reflexes, Penn spasm frequency scale.

Introduction

Spinal cord injury (SCI) results in an insult to the spinal cord leading to change either temporary or permanent in motor, sensory and autonomic functions. It is often associated with many complications that interfere in daily living.

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Lance in 1980 defined spasticity as "spasticity is a motor disorder characterized by a velocity dependant increase in tonic stretch reflexes (muscle tone) with exaggerated tendon jerks, resulting from hyper excitability of the stretch reflex, as one of the component of the upper motor neuron syndrome[1].Spasticity after spinal cord injury results in a complex manifestation of increased skeletal muscle tone, reflex, and clonus, which results from an injury to upper motor neurons. Spasticity is understood to be among the symptom which is not an inevitable sequel of spinal cord injury (SCI).[2].Decq defines spasticity as a symptom of the upper motor neuron syndrome characterized by an exaggeration of the stretch reflex secondary to hyperexcitability of spinal reflexes. He parted this definition into three subclasses (a) intrinsic tonic spasticity: exaggeration of the tonic component of the stretch reflex (illustrated as increased tone), (b) intrinsic phasic spasticity: exaggeration of the phasic component of the stretch reflex (demonstrating as hyperreflexia of tendon and resulting clonus),and the third (c)extrinsic spasticity: exaggeration of extrinsic flexion or extension spinal reflexes[3]. Spasticity can develop following a lesion at any level of the corticofugal pathways–cortex, internal capsule, brainstem or spinal cord. Spastic hypertonia is the exaggeration of the spinal proprioceptive reflexes resulting from a loss of descending inhibitory control. The velocity-dependence of spasticity can be attributed to the velocity sensitivity of the Ia afferents.[4].The frequency of spasticity after spinal cord injury has been observed to be 65-78% of individuals with traumatic spinal cord injury[5].Almost half of them (43-49%) receive pharmacological treatment for this complication[5,6]. Spasticity has likelihood to adversely influence the quality of life (QOL) by impeding activities of daily living (ADL), inducing pain and exhaustion. It may lead to disturbed sleep and discourage effective walking and self-care by contributing in developing contractures, pressure ulcers and infections, which may lead to pessimistic self-image, and curbing the rehabilitation goals[6-8]. It must be noted that, although spasticity can adversely influence quality of life (QOL), it has been suggested that symptoms of spasticity may optimize sitting and standing stability, ease some activities of daily living (ADL) and execution of transfers, augment the muscle bulk and endurance of spastic muscles (thereby helping prevent osteopenia), and boosting venous return (possibly helps in curtailing the incidence of deep venous thrombosis (DVT)[7-9].The aim of this study was to evaluate spasticity in patients of complete motor complete spinal cord injury using M.A.S tool and various other tools of spasticity and assessing their correlation.

Material and methods

Study design, setting and participants

This was a descriptive type of observational cross-sectional study conducted in the spine unit of the Department of Physical Medicine and Rehabilitation in a tertiary care hospital. The study was approved by the institute human ethics committee. A total of 50 chronic (duration ≥ 1 year), motor complete (ASIA scale A or B), spinal cord injured individuals having spasticity in lower limbs , aged between 18-60 years ; BMI between 15- 30 kg/m^2 and those who gave informed written consent were **included** in the study. Patients with a previous history of interventional treatment for spasticity, any co-morbid medical or surgical condition associated with spasticity such as cerebral palsy, traumatic brain injury, stroke etc were **excluded** from the study. A detailed history, clinical examination and relevant investigations of recruited cases were performed in the initial workup. The neurologic assessment and determination of the level was done according to the ASIA impairment scale (American Spinal Injury Association Impairment Scale(AIS)[10]. The following scales were used to evaluate spasticity among group. The Modified Ashworth Scale (MAS)[11] was used for assessing lower limb extensors spasticity. Additionally Spinal Cord Assessment Tool for Spastic Reflexes (SCATS)[12]and the Penn Spasm Frequency Scale(PSFS)[13,14] scores tools were used to assess the spasticity.

Tools to measure spasticity

M.A.S (Modified Ashworth Scale)

The Modified Ashworth Scale (M.A.S)[11]for the knee extensors and ankle extensors was used to evaluate lower extremity spasticity in the supine position. It was measured at the same time of the day (between 8 AM to 9 AM) for all cases. To evaluate spasticity, MAS 1+ was converted to grade 2 and subsequently MAS grade 2, 3, 4 were changed to 3, 4, and 5 respectively. The score of ΣMAS extensor muscle group was calculated using Equations: Eq. (1) to (3), as done in a study by Jung IY et al[15].

Eq.:1. Avg. knee extensor (MAS score): **-**

$$\frac{\text{Right knee extensor + left knee extensor MAS score}}{2}$$

Eq.:2. Avg. ankle extensor (MAS score)**: -**

$$\frac{\text{Right ankle extensor + left ankle extensor MAS score}}{2}$$

Eq.:3. Total MAS (ΣMAS) score**: -** Avg. knee ext. (MAS) score + Avg. ankle ext. (MAS) Score

ΣMAS extensor muscle group score ranges from 0 to 10; study subjects were classified into mild (ΣMAS score of ≤ 2), moderate (ΣMAS score of > 2 and < 4) and severe (ΣMAS score ≥ 4) spastic groups.

Six grades of the modified Ashworth scale[11]

Grade 0- No increase in muscle tone.

Grade 1- Slight increase in muscle tone, manifested by a catch or by minimal resistance at the end of the ROM, when the affected part(s) is moved in flexion or extension.

Grade 2-Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM.

Grade 3-More marked increase in muscle tone through most of the ROM, but the affected part(s) can be easily moved.

Grade 4-Considerable increase in muscle tone, and passive movement is difficult.

Grade 5-Affected part(s) is rigid in flexion or extension.

The Penn Spasm Frequency Scale (PSFS) score[13,14]

It is composed of 2 parts:

1) A self-report measure with items on 5-point scales developed to augment clinical ratings of spasticity and provides a more comprehensive assessment of spasticity.

2) A 3-point scale assessing the severity of spasms.

*****Spasm Frequency:

0 = No spasm.

1 = Mild spasms induced by stimulation.

2 = Infrequent full spasms occurring less than once per hour.

3 = Spasms occurring more than once per hour.

4 = Spasms occurring more than 10 times per hour.

*****Spasm Severity

1 = Mild

2 = Moderate

3 = Severe

* If the patient indicates no spasms in Part 1, then do not proceed to Part 2.

Table 1:The Spinal Cord Assessment Tool for Spastic Reflexes (SCATS)[12]

R	L		
	SCATS: Clonus		Clonus of the plantar flexors is quantified in response to a rapid passive dorsiflexion of the ankle. The ankle dorsiflexed at an angle that triggers clonus, and the duration of clonic bursts is timed.
0	0	no reaction	
1	1	Mild <3 secs	
2	2	3< Moderate <10 secs	
3	3	Severe > 10 secs	
	SCATS: Flexor spasms		With the knee and hip extended to 0°, the clinician applies a pinprick stimulus for 1 second to the medial arch of the subject's foot. Excursion of the big toe into extension, ankle dorsiflexion, and knee and hip flexion is visually observed for severity.
0	0	no reaction	
1	1	less than 10° of excursion in flexion at the knee and hip or extension of the great toe	
2	2	moderate, 10° to 30° of flexion at the knee and hip	
3	3	severe, 30° or greater of knee and hip flexion	
	SCATS: Extensor spasms		With the contralateral limb extended, the tested knee and hip positioned at angle of 90° to 110° of hip and knee flexion, and then both joints simultaneously extended. One hand cupped the heel while the other was placed on the outside of the thigh. Once a reaction is elicited, the duration of visible muscle contraction in the quadriceps muscle is measured by observing superior displacement of the patella.
0	0	no reaction	
1	1	Mild <3 sec.	
2	2	3secs < Moderate <10 sec.	
3	3	Severe > 10 sec.	

Outcomes Variables:

1. The proportion of cases in mild, moderate, severe spastic groups.
2. Mean MAS score.
3. Mean SCATS Score.
4. Mean PSFS Score.

Statistical analysis

Demographic data were presented with means ± standard deviations or in percentage. The qualitative data were expressed in proportion and percentages and the quantitative data expressed as mean and standard deviations. The difference in proportion was analyzed by using the chi-square test. The difference in means among the groups was analyzed using the ANOVA (Analysis of variance test). Correlation between quantitative outcomes was assessed using the Pearson correlation coefficient. The Statistical Package for Social Sciences (SPSS trial version 23.0) was used for statistical analysis. The significance level for tests was determined as 95% ($P < 0.05$).

Results

Demographic profile

In the present study, among the 50 participants of SCI, 84 %(n=42) were males and 16 %(n=8) were females, 72 % (n=36) were married, 94 %(n=47) belonged to 20-50 yrs age group. Among the causes of injury, 52.5% had fall from height while 26.5% had a road traffic accident. Among the study population, 52 % (n=26) were quadriplegic who had higher level injury i.e. cervical injury while 48% (n=24) were paraplegic who had lower level spine injury i.e. thoracic injury. It was observed that 46% (n=23) individuals had severe spasticity in lower limbs while 22% (n=11) had moderate and 32% (n=16) had mild spasticity. All the three groups of spasticity i.e. mild, moderate and severe spastic cases were comparable as per age, gender, and level of injury. (Table2)

Table 2: Distribution of Paraplegics and Quadriplegics on basis of severity of spasticity.

	MILD		**MOD**		**SEV**		**Grand Total**	
	N	%	N	%	N	%	N	%
PARAPLEGIA	11	68.75	7	63.636	6	26.087	24	48
QUADRIPLEGIA	5	31.25	4	36.364	17	73.913	26	52
Total	**16**	**100**	**11**	**100**	**23**	**100**	**50**	**100**

Chi-square = 8.262 with 2 degrees of freedom; P = 0.016 S

Spasticity outcome measurement

The mean M.A.S score among the study group was 3.71±1.60. The grading of spasticity was correlated significantly with the M.A.S score (P<0.001S). Quadriplegics (higher level cervical injury group) had predominantly severe spasticity (73%; n= 26) while paraplegics (lower level thoracic injury group) predominantly had either mild or moderate spasticity. (26%; n=24; P = 0.016 S).(Table 2,3)

Table 3: Association of ∑ MAS EXT score with the different grade of spasticity.

		N	**Mean**	**Std. Deviation**	**ANAOVA***	**1 vs 2**	**1 vs 3**	**2 vs 3**
∑ MAS EXT score	Mild	16	1.84	0.30	<0.001S	<0.001S	<0.001S	<0.001S
	Mod	11	3.14	0.32				
	Severe	23	5.28	0.54				
	Total	**50**	**3.71**	**1.60**				

Anova* : analysis of variance

The mean SCAT ankle clonus score, flexor spasm score and extensor spasm score were 1.55±1.05, 1.36±0.81 and 1.22±0.76 respectively (P<0.001S). A significant positive correlation was observed between the mean SCAT and M.A.S score(r = 0.913).(Table 4,6)

Table 4: Association of SCAT Score and different grades of spasticity

		N	Mean	Std. Deviation	ANAOVA*	1vs 2	1vs 3	2vs3
SCAT:AC	Mild	16	0.41	0.27	<0.001S	<0.001S	<0.001S	<0.001S
	Mod	11	1.18	0.64				
	Severe	23	2.52	0.44				
	Total	50	1.55	1.05				
SCAT: FS	Mild	16	0.56	0.25	<0.001S	0.54NS	<0.001S	<0.001S

	Mod	11	0.91	0.44				
	Severe	23	2.13	0.41				
	Total	50	1.36	0.81				
SCAT:ES	Mild	16	0.47	0.29	<0.001S	0.25NS	<0.001S	<0.001S
	Mod	11	0.91	0.44				
	Severe	23	1.89	0.48				
	Total	50	1.22	0.76				
MEAN SCAT	Mild	16	0.48	0.19	<0.001S	<0.001S	<0.001S	<0.001S
	Mod	11	1.00	0.44				
	Severe	23	2.17	0.29				
	Total	50	1.37	0.83				

Anova* : analysis of variance

The mean PSFS (frequency) score in mild spastic group and in severe spastic group was 0.94±0.25and 2.52±0.51 respectively (P<0.001S). The mean PSFS (severity) score in mild spastic group and in severe spastic group was 0.94±0.25and 2.13±0.55 respectively. (P<0.001S) A significant positive correlation was observed between M.A.S score and the mean PSFS(FREQ; r = 0.856) score and PSFS(SEV; r = 0.818) score.(Table 5,6)

Table 5 : Association of PSFS score with different grades of Spasticity

	Type of spasticity	**N**	**Mean**	**Std. Deviation**	**ANAOVA***	**1VS 2**	**1vs 3**	**2vs3**
PSFS: FREQ	Mild	16	0.94	0.25	<0.001S	0.013S	<0.001S	<0.001S
	Mod	11	1.45	0.52				
	Severe	23	2.52	0.51				
	Total	50	1.78	0.84				
PSFS: SEV	Mild	16	0.94	0.25	<0.001S	0.155NS	2.00NS	<0.001S
	Mod	11	1.27	0.47				
	Severe	23	2.13	0.55				
	Total	**50**	**1.56**	**0.70**				

Anova* : analysis of variance

Discussion

In the present study, male to female ratio was greater than 5:1. Most cases belonged to a young to middle age group as this age group being more active and engaged in day to day activities. Fall from height and road traffic accidents remained the most common causes of spinal cord injury reflecting lack of awareness among the people for the use of protective gears and safety measures while driving, in transport, or during work hours. Complete paralysis was found in 52% cervical spine injury (higher level spine injury) and 48% thoracic spine injury (lower level spine injury). The involvement of a primary earning younger member of family in sustaining spinal cord injuries leads to major psychological and financial impact on the families for long term thus generating a need of prevention of such vital injuries.In present study, severe spasticity (73.91%) was observed more in quadriplegic cases while paraplegics cases predominantly had mild (68.75%) and moderate(63.64%) spasticity and this observation was statistically significant (P=0.016S). This outcome implies that individuals having cervical injuries experience severe spasticity as compared to those having thoracic spinal injuries. A similar result was seen in a study conducted by Maynard FM et al[6] which stated that incidence of spasticity was higher among cervical and upper thoracic than lower thoracic and lumbosacral levels of injury groups. This consequence is also in consonance to a study done by Gorgey A.S et al[16] to determine the effects of the level of spinal cord injury (SCI) to spasticity in which they concluded that spasticity was significantly evident in the high-level injury (HLI;C5-C7) group compared to low-level injury (LLI; T12-L2) group. Modified Ashworth Scale which is rating a resistance to passive velocity dependant movement through the full range of motion about a single joint for a relaxed target muscle, is well tolerated and acceptable tool.

Table 6 : Correlation between ∑ MAS EXT, SCAT and PSFS scale.

	∑ MAS EXT		
	Pearson Correlation	**Sig. (2-tailed)**	**N**
MEAN SCAT	.913**	<0.001S	50
PSFS: FREQ	.856**	<0.001S	50
PSFS: SEV	.818**	<0.001S	50

** Pearson correlation

The Ashworth spasticity scale which was developed to assess antispastic effects of carisoprodol in multiple sclerosis[17], is a five-point nominal scale focusing on the subjective clinical assessment of tone. For the MAS, an additional grade was added (1 +) to enhance sensitivity to accommodate hemiplegic patients who graded typically at the lower end of the scale, more specifically to measure elbow flexor spasticity in patients with multiple sclerosis.[11] Although the Modified Ashworth Score (MAS) is the most commonly used tool for assessing spasticity in clinical practice and research, the reliability and validity of this scale remain unclear.[18] Moreover, the degree of spasticity can vary according to the patient's physical and emotional conditions, even within a single day.[19] Additionally M.A.S only addresses the velocity dependant aspect of spasticity across a single joint. Therefore for a factual assessment of the spasticity differences among the groups, we used the spinal cord assessment tool for spastic reflexes (SCATS) score and the Penn Spasm Frequency Scale (PSFS) score. Moreover Benz EN observed that PSFS was found to correlate highest with the SCATS clonus measure as compared to the flexor and extensor spasm components of SCATS, suggesting that the role of clonus represents the client's highest perception of spasticity[12].SCI reflex hyper excitability is described frequently as including clonus and, flexor and extensor spasms.

The spinal cord assessment tool for spastic reflexes (SCATS) scale was developed by Benz et al.[12] to measure SCI spasms and spastic hypertonia. Thus SCATS measures spastic reflexes of individuals with spinal cord injury (SCI). Present study depicts that spinal cord assessment tool for spastic reflexes (SCAT) score was significantly associated with the type of spasticity (P≤0.001S). All three variables studied SCAT ankle clonus (SCAT: AC); SCAT flexor spasm (SCAT: FS); and SCAT extensor spasm (SCAT: ES) were found to be significantly positively correlated with a grade of spasticity. The mean SCAT was significanlty higher (2.17±0.29) in severe as compared to mild and moderate grade of spasticity.(0.48 ±0.19 ; 1.00±0.44 respectively; P<0.001S). Spasticity was significantly associated with the SCAT score (P <0.001S). As per JTC Hsieh1 et al[20]. SCAT is simple and easy to administer as it is comprised of elements common to a standard neurological examination of lower extremities. As reported by Benz et al[12], SCATS could provide additional information on multi joint spasticity in comparison to the AS and M.A.S which are limited to spasticity assessment over a single joint.

Penn et al.[13] originally defined a five-point spasm frequency scale, which was later modified by Priebe et al.,[14] and referred to as the modified PSFS. The modified PSFS is a two component self-report scale to provide spasticity ratings and more comprehensive understanding of severity of spasticity of an individual. The first component is a five point scale assessing frequency of spasms from zero (no spasms) to four (spontaneous spasm> 10 per hour). The second component is a three-point scale assessing the severity of spasms (from '1 = mild' to '3 = severe'). The second component is not answered if the person indicates that they have no spasms in part 1. PSFS is a very simple tool to measure spasticity and do not require any special hospital settings or equipments. It is a self-reported measure that appraises an individual's awareness of spasticity, frequency, and severity. In present study it was found that both the mean PSFS frequency score and the mean PSFS severity score were found to be significantly associated with the type of spasticity (P≤0.001). The mean PSFS frequency score of severe spastic patients was 2.52±0.51, which was significantly higher than the mild or moderate spastic group (0.94±0.25; 1.45±0.52; P<0.001S). The mean PSFS severity score of severe spastic group was 2.13±0.55 which was significantly higher than the moderate spastic group (1.27±0.47; <0.001S).However the difference in mean PSFS severity score of mild (0.94±0.25) and moderate spastic group was not significant. Our study results are in accordance to a study done by Jung IY et al (2017)[15] in which both SCATS and PSFS scores were significantly higher in a severe spastic group than a mild spastic group.Seungwoo C et al [21] also recently concluded that all spasticity scales(spasticity sum score (SSS), Penn Spasm Frequency Scale(PSFS), and Spinal Cord Assessment Tool for Spastic Reflexes (SCATS) were significantly associated with skeletal muscle index of lower extremities.

Conclusion

Present study identified three spasticity outcome measures tools referenced in the current spinal cord injury literature as M.A.S, PSFS and SCATS. All these three tools are easy to administer, no specialized equipment are needed, well tolerated by patients i.e. both acceptability and feasibility were good, have a good clinical utility and correlate well with the severity of spasticity. The validity and responsiveness of these tools need to be addressed in further studies. In this study, both SCATS score and PSFS score were found to be positively correlated with the M.A.S. Since in literature, it has been suggested that no single outcome measure can reflect the multidimensional nature of spasticity due to its velocity dependency, frequency, severity, subclinical conditions, tonic spasticity (tone), phasic spasticity (hyperreflexia, clonus) and involuntary muscle spasms and so on[14,22] , focusing on only few measures may lead to under reporting or over reporting of magnitude of spasticity[14].So, it has been suggested that a battery of tests should be applied to measure spasticity variables[22]. In the developing field of rehabilitation, we should aim to develop a suitable choice of standard battery of tests to assess severity of spasticity considering its multidimensional nature, thereby providing better antispastic interventions.

Abbreviations

SCI: Spinal cord injury, M.A.S: Modified Ashworth scale, SCATS: Spinal cord assessment tool for spastic reflexes, PSFS: Penn spasm frequency scale.

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