Neurophysiological examination of the Modified Modified Ashworth Scale (MMAS) in patients with wrist flexor spasticity after stroke

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Neurophysiological examination of the Modified Modified Ashworth Scale (MMAS) in patients with wrist flexor spasticity after stroke

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Abstract

The Modified Modified Ashworth Scale (MMAS) is a clinical test for the measurement of spasticity. The aim of the present study was to examine the validity of the MMAS in patients with wrist flexor spasticity after stroke. 27 adult patients (14 women and 13 men) with first ever stroke resulting in hemiplegia with a mean (SD, range) age of 57.9 (11.6, 37-75) were included in the study. The outcome measures were the MMAS for the clinical assessment of spasticity, the Hslope/Mslope (Hslp/Mslp), and the Hmax/Mmax ratio for the neurophysiological evaluation. The mean of the Hslp/Mslp and the Hmax/Mmax were higher in patients with worse MMAS grades but the differences were not statistically significant. There was a significant positive correlation between the MMAS scores and Hslp/Mslp ratio as the new index of alpha motoneurone excitability or traditional index of Hmax/Mmax ratio ($r = 0.39$, $p = 0.04$). It is concluded that the MMAS to be a valid measure ofspasticity after stroke.

Key-words: Spasticity – Validity – Modified Modified Ashworth Scale – H-reflex.

Introduction

Stroke is a common and serious condition that has been described as a catastrophic life event (1, 2). It is a leading cause of disability in the industrialized world (3, 4). Each year 750,000 subjects suffer a stroke in the United States (3). Approximately 90% of stroke patients experience neurological motor deficits that lead to disability and handicap (5). The ischemia is a major cause of neuronal loss and subsequent disability following stroke. Damage to the pyramidal and para-pyramidal tracts lead to motor deficits (6).

Spasticity is a hallmark component of the upper motor neuron (UMN) syndrome that could be present in more than a third of all patients at a year following stroke (4, 7). The prevalence is reported to be 35% in stroke patients (8). A higher prevalence of 67-78% and 85% has been reported for patients with multiple sclerosis and spinal cord injuries, respectively (9, 10). The generally accepted definition of spasticity is that of Lance (1980) "..a velocity dependent increase in the tonic stretch reflex (muscle tone) with exaggerated tendon reflexes, resulting from the hyperexcitability of the stretch reflex, as one component of the UMN syndrome" (11). The increased excitability of the stretch reflex is a major component of the definition of spasticity (12). Furthermore, the literature indicates that

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significant structural alterations in muscle occur after spasticity (13). However, the pathophysiology underlying alterations in skeletal muscle that contributes to the deficits is not clearly known (14). Spasticity is associated with contractures, stiffness, pain and weakness. These, combined with decreased voluntary motor strength, balance deficits, and impaired sensory-motor control, can lead to functional limitations (14-17). Functional ability in spastic patients can be compromised but the basic mechanisms underlying these deficits are not clearly recognized (14).

The evaluation and treatment of spasticity is a major part in neurological rehabilitation. The clearly defined goals and outcome measures are important in the management of spasticity (4, 18). Clinicians need reliable and valid measures of spasticity to assess patients and to determine more accurately the effects of drugs and therapeutic interventions. The MMAS is a clinical rating scale to measure spasticity (19). This scale is a 5-point scale to quantify the muscle spasticity during passive stretching (table 1). In the only study to investigate the validity of the MMAS, Naghdi et al. (2007) (20) used the H-reflex parameters of Hmax/Mmax, and Hslp/Mslp as novel index of alpha motoneuron excitability (21) in the post-stroke wrist flexor spasticity. In the impaired upper limb of 12 patients, they found no relationship between the clinical scale of MMAS and either the traditional [Hmax/Mmax ratio ($r = -0.06$)] or the new index [Hslp/Mslp ($r = 0.24$)] of spinal excitability. Naghdi et al. (2007) included a small sample of patients and suggested a further study with larger number of patients to draw a firm conclusion (20). Therefore, the aim of this study was to examine the validity of the MMAS by using H-reflex as a neurophysiological technique for the assessment of spasticity, in the upper limb in post-stroke hemiplegia.

Methods

Subjects

27 adult patients with first ever stroke resulting in hemiplegia were included if they were able to comply with the study protocol, had a clinically detectable increase in muscle tone and were not taking antispastic drugs. Those with fixed muscle contractures and pain at the wrist joint, contraindications to passive movements, diabetic neuropathy, and discopathy were excluded. Prior to testing, all subjects provided written informed consent directly or via a care giver as approved by the research board of rehabilitation faculty, Iran University of Medical Sciences.

The main outcome measures were the Modified Modified Ashworth Scale (MMAS) for the clinical assessment of spasticity, the Hslp/Mslp and the Hmax/Mmax ratio for the neurophysiological evaluation. The measurements were made in a same session and the assessment of spasticity using the MMAS was always carried out first.

Procedure

Demographic data were collected from subjects to document age, gender, the time post-injury, cause, and affected side. Muscle tone of wrist flexors graded according to the MMAS (19), which describes the resistance to passive movement throughout joint range of motion. A single examiner experienced at using MMAS, measured muscle spasticity at the wrist joint. In all cases, clinical measure of muscle spasticity was obtained followed by H-reflex measurements. All neurophysiological measurements were performed by a trained clinician.

The Modified Modified Ashworth Scale

Spasticity of the wrist flexors was assessed clinically with the MMAS (table 1). The tests were carried out by one experienced physiotherapist. The spasticity was measured at the wrist joint of the impaired upper limb with the patient in the supine position. The interrater reliability of this scale has been proven when applied at the wrist joint in adult hemiplegic patients (20).

H-Reflex Evoking Techniques

The patients underwent a neurophysiologic study of both affected and unaffected sides to assess maximum H-reflex and maximum M-wave. The H-reflex

Table 1. – *Definitions of the Modified Modified Ashworth Scale*

Grade	Modified Modified Ashworth Scale (Ansari et al., 2006)
0	No increase in muscle tone
1	Slight increase in muscle tone, manifested by a catch and release or by minimal resistance at the end of the range of motion when the affected part(s) is moved in flexion or extension.
2	Marked increase in muscle tone, manifested by a catch in the middle range and resistance throughout the remainder of the range of motion, but affected part (s) easily moved
3	Considerable increase in muscle tone, passive movement difficult
4	Affected part(s) rigid in flexion or extension.

has been shown that can be reliably assessed (22, 23). The H-reflex is evoked by electrical stimulation of a mixed nerve which will activate the Ia afferents. The sensory endings of the muscle spindle organs are bypassed, and the excitability of the neural components of the arc is measured irrespective of sense organ sensitivity (24, 25). The recordings from the unaffected side were used as a control. The H-reflex and the M-wave were obtained with the MytoII EMG machine (Italy). The bandpass filter was set at 5 Hz to 3 kHz, sweep rate at 5 ms/div, and sensitivity at 500μV to 2 mV/div was used. Rectangular electric pulses, 1 ms in duration, were repeated every 5 seconds the output of which ranged from 0-100 mA. The procedure described by Jabree (26) was followed. A bipolar stimulating ball electrode was used to stimulate the median nerve at the elbow crease. The recording electrodes were placed over the muscle belly of Flexor Carpi Radialis (FCR). Paired surface electrodes (Ag/AgCl) were used. Active electrode was placed on the belly of FCR at one third of the proximal distance between the medial epicondyl of humerus and the radial styloid. The electric resistance between the two electrodes was less than 10 kΩ. The ground was attached to the skin between stimulating and recording electrodes. The H-reflexes and M-waves recorded in response to stepwise increases in stimulus intensity from below threshold for the H-reflex to that eliciting a maximal M-wave. The intensity of pulses was gradually increased with 0.5 mA steps.

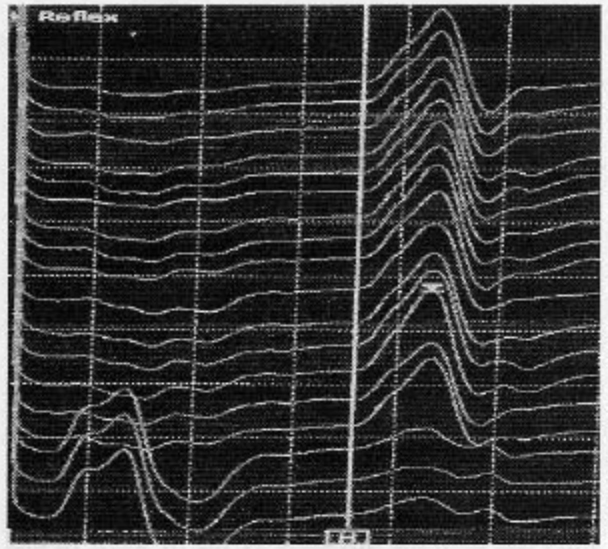

Fig. 1. – H-reflexes and M-waves.

The measures were made with the forearm fully supinated. The neurophysiological tests in either affected or unaffected side were randomly assigned. The amplified signals were digitized and stored in the PC computer for subsequent calculation of the neurophysiological parameters. Figure 1 shows a sample of H-reflexes and M-waves.

Recruitment curves

To produce recruitment curves, data were collected in accordance with the Funase et al. (21, 27). Three pulses were collected at each stimulus intensity and the mean was calculated.

The amplitudes of the H-reflexes and M-waves were measured Peak-to-peak, from the largest peak of the positive to the largest peak of the negative deflections from the baseline. The mean of the three H-reflexes and M-waves obtained at each stimulus intensity was expressed as a percentage of the maximal M-wave (Mmax; the mean maximal amplitude was calculated from all maximal M-waves evoked at the highest stimulus intensity). Stimulus intensity was presented as the ratio to the threshold of the M-wave (Mth). Hmax was defined as the highest mean amplitude (relative to the mean maximal amplitude of the M-responses) of three H-reflexes.

The equation of the simple linear regression line fitted to the recruitment curve of the H-reflex was

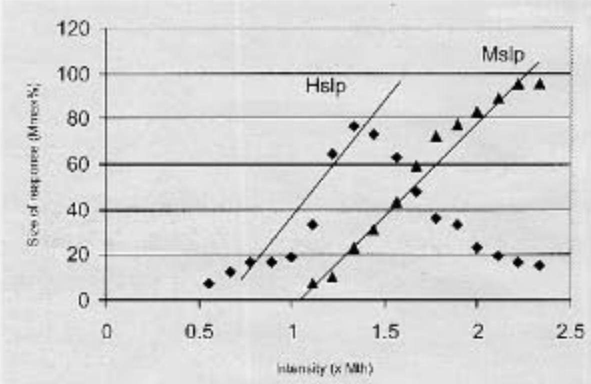

Fig. 2. – Hslp and Mslp in a patient with MMAS grade of 3.

calculated from all data measured at stimulus intensities less than the threshold of the M-wave. In this way, the rate of the ascending slope rise was calculated. The slope of the regression line of the H-reflex was considered as Hslope (Hslp). The slope of the regression line of the M-wave was calculated in a similar manner from all M-wave data and called Mslope (Mslp). A sample of the recruitment curves recorded from a patient with a MMAS score of 3 is illustrated in figure 2.

Data were analysed by using the Hslp/Mslp ratio and the Hmax/Mmax ratio. The parameter of Hmax/Mmax ratio compares the maximal H-reflex to that of the M-wave, and reflects the maximal number of alpha motoneurons firing. The Hslp/Mslp ratio has been claimed as a more sensitive measure at assessing excitability of the motor neuron pool as it excludes alterations in peripheral factors from influencing H-reflex amplitude (21, 27).

Statistical analysis

The correlation between the MMAS scores and the H-reflex indicators was calculated using the Spearman's rho test. The strength of correlations was interpreted as shown in table 2 (28).The Kruskal-Wallis test was used to compare groups of patients with different MMAS scores on the spinal excitability measures. The difference in neurophysiological variables between the affected and the unaffected sides was analysed with Wilcoxon Signed Ranks Test (WSRT). The statistical procedures were carried out using SPSS (v 11.5).

Table 2. – *Interpretation of the correlations**

Strength of Agreement	Correlation
low	0.00 – 0.39
moderate	0.40 – 0.59
Moderately high	0.60 – 0.79
high	0.80 – 1.00

* Platz et al. (2005)

Table 3. – *The neurophysiological data in different MMAS* grades*

Variables	MMAS grades	Mean (SD)	Minimum	Maximum
Hmax/ Mmax	0	0.17 (0.06)	0.12	0.23
	1	0.43 (0.23)	0.13	0.73
	2	0.49 (0.36)	0.09	0.94
	3	0.57 (0.24)	0.28	1
Hslp/ Mslp	0	0.69 (0.44)	0.20	1.03
	1	0.93 (0.67)	0.22	1.81
	2	1.02 (1.28)	0.12	3.90
	3	1.72 (0.89)	0.65	3.50
Hslp	0	29.58 (16.01)	11.94	43.19
	1	88.94 (76.53)	18.23	191.47
	2	111.49 (97.73)	15.29	321.19
	3	179.84 (127.99)	25.92	434.9

* MMAS, Modified Modified Ashworth Scale

Results

27 patients (14 women and 13 men) who fulfilled the study entry criteria completed the evaluation. Patients were grouped according to the clinical severity of the spasticity, as rated by the MMAS. The patients scored 0 (n = 3, 11.1%), 1 (n = 6, 22.3%), 2 (n = 8, 29.6%) or 3 (n = 10, 37%) on the MMAS. The mean age of patients (SD, range) was 57.9 (11.6, 37-75) years. Patients had a mean (SD, range) time since the stroke onset of 20.8 (3.51, 4-24) months.

The mean (SD, range) of the Hslp/Mslp and Hmax/Mmax ratio was1.22 (0.98, 0.12-3.9) and 0.47 (0.27, 0.09-1), respectively. The mean (SD, range) of the Hslp was 122.69 (109.30, 11.94-434.90). They were higher in patients with worse MMAS grades (table 3) but the differences were not statistically significant.

A significant positive correlation was found between the MMAS scores and neurophysiological data [Hslp/Mslp ratio ($r = 0.39$, $p = 0.04$), Hmax/Mmax ratio ($r = 0.39$, $p = 0.04$), and Hslp ($r = 0.45$, $p = 0.02$)].

In only 6 of the 27 patients, the H-reflex was elicitable from the unaffected side. The difference in neurophysiological parameters was statistically significant between two sides ($p < 0.05$).

Discussion

The aim of this study was to examine the validity of the MMAS in post-stroke hemiplegia with wrist flexors spasticity, using a new index of alpha motoneuron excitability, Hslp/Mslp. The results showed a significant linear correlation between the clinical scale of MMAS and alpha motoneurone excitability indicators (Hslp/Mslp and Hmax/Mmax ratio). Muscles scoring high on the MMAS are more likely to show higher Hslp/Mslp and Hmax/Mmax ratio.

The results of the present study are not consistent with previously reported findings on H-reflex and relationships with MMAS clinical scale (20). The reason may be the larger number of the patients recruited for this study. In contrary to the former study which included 12 patients with MMAS scores of 1, 2 and 3, the patients in this study had the MMAS scores ranged from 0 to 3, but were ranged most frequent in the high end of the scale representing the highest levels of spasticity. Patients with significant contracture were excluded. A study showed that in the absence of significant contracture, it is unlikely the mechanical factors such as muscle contractures to participate in the resistance to passive movement (29). This indicates that neural contribution to resistance was examined in clinical judgement of muscle spasticity to ensure that both clinical and neurophysiological measures test the stretch reflex excitability.

Our results showed that the spasticity scores of MMAS had significant positive correlation with stretch reflex excitability measures of Hslp/Mslp and Hmax/Mmax ratios. However, a significant higher correlation was found between the Hslp and the MMAS scores. The MMAS may therefore accurately reflect the spasticity in stroke patients. The H-reflex is a widely used and valuable tool for investigating excitability of the stretch reflex, both in clinical and research setting (22, 24). The Hmax/Mmax ratio which show the maximal percentage of firing motorneurons (MNs) has some methodological problems and can be decreased by collision occurring between a descending H-reflex discharges and ascending antidromic motor volley within the alpha motor axons as the strength of the M-response increases (27).The alternate measure of the H-reflex arc has been suggested to avoid these limitations (21). Funase et al. (1994) refer to the slope of the regression line of the H-reflex as a parameter for the 'reflex gain' against which the excitability of an MN pool can be evaluated (21). The Hslp/Mslp is propsed as a new method to evaluate the excitability of the MN pool, because it is not affected by suppression of the H-reflex associated with collision phenomenon (27). This method has recently been used clinically in assessment of recovery of patients with hemiplegia, and the authors concluded that the Hslp/Mslp is the preferred index for evaluating the motoneuron pool excitability of the affected side in patients with hemiplegia (30). Funase et al. (1994) have also suggested the Hslp/Mslp as a more sensitive parameter than the Hslp alone (21). However, the higher correlation between the Hslp and the MMAS scores may indicate that the Hslp is a valid and sensitive measure of changes in alpha motoneurons excitability.

A similar significant positive correlation was observed between the MMAS scores and both Hslp/Mslp and Hmax/Mmax ratios. This finding may indicate that both traditional and novel indicators of H-reflex have a similar sensitivity to measure muscle spasticity. A study to determine the relationship between the Modified Ashworth Scale (MAS) with the measures of Hslp/Mslp and Hmax/Mmax ratio in the assessment of ankle plantar flexor, found a significant correlation with only the later measure (31). The discrepancy between this study and that of Ghotbi et al. (2006) may be that they used the data points in the central two thirds of the linear portion of the H-reflex and M-wave recruitment curves to calculate the rate of rise of the ascending slope (31). Funase et al. (1994) suggested the calculation of the slope using a linear regression, which was a least-squares fit to the ascending limb of the recruitment curve (21). In the present study, the method proposed by Funase et al. (1994) was followed (21). One explanation may be that the modifications made with the MAS have resulted in a reliable and valid measure of spasticity, MMAS (19). It may also be assumed that MAS has a lower reliability at the ankle (32, 33). In addition, the Hmax/Mmax ratio may be assumed as a more sensitive index than the Hslp/Mslp where it is correlated with both the MAS (e.g. 31, 34) and the MMAS in the present study. However, there is one study that observed no linear relationship between the MAS scores and Hmax/Mmax ratio (35).

The low correlation between clinical measure of MMAS and neurophysiological indicators was demonstrated. A limited range of scores may be a reason which may have attenuated the correlations. No Patient with a MMAS score of 4 was scored. Stronger correlations might have been demonstrated if the full range of spasticity had been tested, or if larger numbers of patients with lower MMAS scores had been included. The low correlations observed in the present study may be interpreted in light of the fact that the neurophysiological methods including H-reflex have limitations and tend to correlate poorly with the clinical severity of spasticity (36, 37).

There was a hierarchical increase in the mean values of the Hslp/Mslp and the Hmax/Mmax ratio with the MMAS scores. The neurophysiological data were higher in the group of patients with higher score on the MMAS than in those who had a lower score. However, the differences between the groups were not statistically significant. One possible explanation may be the small number of patients included with each grades on MMAS. A recent report on the validity of the modified Ashworth scale found that the mean rank in the values of the Hslp/Mslp and Hmax/Mmax ratio was lost, and the MAS score '1 +' was the error point (31). These findings validate the discussion made by Ansari et al. (2006) that named the '1 +' as the center of disagreement between raters and omitted the '1 +' (19).

Conclusion

Spasticity can compromise the functional ability of the spastic patients. There is a need to use a valid and reliable tool to measure the spasticity changes. The results of present study showed a significant positive correlation between the MMAS scores and the Hslp/Mslp ratio as the new index of alpha motoneurone excitability or traditional index of Hmax/Mmax ratio. The MMAS was demonstrated to be a valid measure of spasticity in patients with stroke.

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