Electrophysiologic assessment of spasticity in children using H-reflex

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We investigated a possible correlation between Hoffmann's reflex (H-reflex) and the Modified Ashworth Scale (MAS) in children with spasticity. H-reflex latencies, amplitudes (H amplitude), Hmax/Mmax amplitude, and MAS were simultaneously measured in 30 children who had bilateral spasticity on the lower extremities. Children with MAS scores of 1 and +1 composed Group I (n=11), and children with MAS scores of 2 and 3 composed Group II (n=26) and Group III (n=23), respectively. The H-reflex latencies were significantly shorter and Hmax/Mmax ratios were significantly higher in patients with cerebral palsy than controls irrespective of the degree of the MAS. The H-reflex latencies in patients with MAS of 1 or +1 were significantly longer than in patients with MAS of 2. Other than between these two groups for H-reflex latencies, no significant differences were revealed among the three different MAS groups for either H-reflex latencies or Hmax/Mmax ratios. There is a positive correlation between spasticity assessed by MAS and H-reflex. We concluded that the H-reflex is a reliable electrophysiologic test for assessment of spasticity in children.

Key words: spasticity, children, Modified Ashworth Scale, H-reflex, cerebral palsy.

Spasticity is one of the most common disorders in children with central nervous system diseases[1,2]. However, identifying the degree of spasticity is still a challenging problem in clinical practice.

Several clinical and electrophysiologic tests are used for the assessment of the severity of spasticity[3-8]. Electrophysiological studies (Hoffmann's (H)–reflex and F-waves) are suggested as more reliable measures of muscle spasticity in children. The H-reflex, exclusively monosynaptic, has been shown to be an effective measure of alpha motor neuron excitability in children with cerebral palsy[9-13].

The Modified Ashworth Scale (MAS) is the most widely used clinical test for the assessment of muscle spasticity[6-8]. However, few studies have addressed combining the H-reflex response and MAS[7,14,15]. There are controversies about its validity in clinical practice. MAS should be supplemented by at least one other clinical or electrophysiological test.

In this study, we aimed to test the clinical applicability of H-reflex response compared to that of the MAS in children with spasticity.

Material and Methods

Thirty children with spasticity (18 males, 12 females) with a mean age of 40.5±13.7 months and 25 healthy children (12 males, 13 females) with a mean age of 52.4±15.6 months were included in the study. Children with fixed muscle contractures at the ankle joint were excluded.

The MAS and neurophysiological test (H-reflex) studies were performed in the same session. The relevant ethics committee approved this study, and written consent was obtained from the parents of all participants.

Hoffmann's Reflex (H-reflex) Studies

H-reflex and the M-wave measures were determined with an electromyography (EMG) machine (Medelec, Sapphire 4ME, Waking, Surrey, United Kingdom). The test was performed with the patient in the prone position with their feet suspended over the end of the bed and their head resting on a pillow. Bipolar surface bar electrodes (Medelec, recording surface area 2 cm^2, interelectrode distance 1 cm) were applied. Before the application of the electrodes, the skin was cleaned until a skin impedance of less than 10 kOhm was obtained. Electrophysiological responses were recorded with an active surface electrode taped posteriorly over the gastrocnemius/soleus muscle complex at its greatest circumference and a reference electrode placed over the proximal Achilles tendon. The tibial nerve was stimulated with a rectangular electrical pulse of 1 ms duration applied once every five seconds. The stimulation procedure followed that of Braddom and Johnson[9]. The optimal position for stimulating the tibial nerve in the popliteal fossa was determined by moving the stimulating electrode around until a visible contraction of the gastrocnemius muscle was observed. Following this procedure, the current was gradually increased until an H-reflex without an M response was recorded. The largest amplitude response observed without an M response was designated as the Hmax. The stimulus intensity was then further increased in small increments until the maximum M response was obtained. The H-reflex was identified as a triphasic wave with a small initial positive deflection followed by a larger negative one.

The maximum amplitudes of the H-reflex and the M-wave were measured as the difference between the peaks of the positive and negative deflections. The Hmax to Mmax ratio was calculated by dividing the maximum amplitudes of the H-reflex by that of the M-wave. The H-reflex latency was measured from the beginning of the stimulation to the onset of the initial deflection of the H-reflex.

The Modified Ashworth Scale (MAS)

As shown in Table I, the MAS was performed for assessment of the degree of muscle hypertonia on a six-point scale ranging from 0 to 4 (0, normal muscle tone; 4, fixed muscle contracture).

Statistical Analysis

For statistical analyses, patients were divided into three groups based on the degree of clinical spasticity, as measures by the MAS: Group I included patients with MAS scores of 1 or +1, Group II included patients with MAS scores of 2, and Group III included patients with MAS score of 3. The results of tests of the H-reflex were compared with MAS scores in each group by using the Mann-Whitney U test. The Kruskal-Wallis test was used to compare the three groups.

Results

Sixty MAS scores and H-reflex responses were obtained from the bilateral lower extremities of 30 children with spasticity. The degree of spasticity was graded based on MAS scores; Group I (n: 11) = MAS scores of 1 or +1, Group II (n: 26) = MAS scores of 2, and Group III (n: 23) = MAS scores of 3.

The H latencies were significantly shorter in all three groups of children with spasticity than in the healthy controls ($p<0.05$) (Table II). The mean value of H latencies were significantly shorter in children with spasticity (Group I: 17.3±SD msec, Group II: 16.1±SD msec, Group III: 16.2±SD msec) when compared to the mean value in healthy controls (18.7±SD msec).

The mean values of the Hmax/Mmax amplitude ratios were significantly higher in children with spasticity (Group I: 0.33±SD, Group II:

Table I. The Modified Ashworth Scale (MAS)

0	No increase in muscle tone
1	Slight increase in muscle tone, manifested by a catch and release or minimal resistance at the end of the range of motion (ROM) when the affected part is in flexion or extension.
+1	Slight increase in muscle tone, manifested by a catch followed by minimal resistance throughout the remainder (less than half) of the ROM.
2	More marked increase in muscle tone through most of the ROM, but the affected part moved easily.
3	Considerable increase in muscle tone, passive movement difficult.
4	Affected parts rigid in flexion and extension.

Table II. H-reflex Responses in Children with Central Spasticity Grouped Based on Modified Ashworth Scale (MAS) Scores

	Group I (n=11) MAS score 1 or +1	Group II (n=26) MAS score 2	Group III (n=23) MAS score 3	Controls (n=24)
H latency	17.3±6.3	16.1±5.2	16.2±6.1	18.7±7.2
Hmax/Mmax amplitude ratio	0.33±0.12	0.36±0.11	0.37±0.06	0.26±0.09

($p<0.05$)

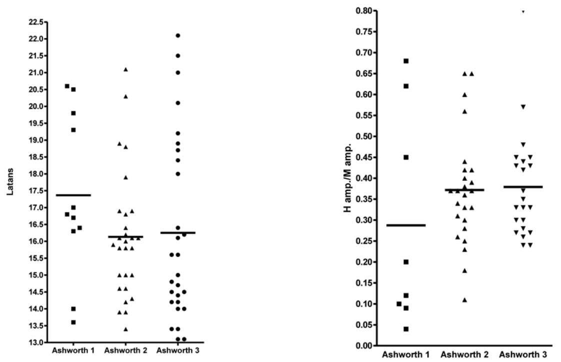

Fig. 1. H-reflex responses (H latency and Hmax/Mmax ratio) in children with spasticity grouped based on the Modified Ashworth Scale (MAS) scores.
A. H-reflex latency B. Hmax/Mmax ratio

0.36±SD, Group III: 0.37±SD) than those of healthy children (0.26±SD).

Comparison of H latencies and Hmax/Mmax amplitude ratios between the groups with spasticity revealed significant differences only between Groups I and II for H-latencies ($p<0.05$) (Fig. 1A). The correlation between the H responses and the MAS scores of children with spasticity was also investigated. There was a slightly positive correlation between Hmax/Mmax amplitude ratios and MAS scores that did not reach statistical significance ($p>0.05$) (Fig. 1B).

Discussion

Combining clinical and neurophysiological methods to assess spasticity remains an important challenge in children with cerebral palsy. The MAS is used extensively for qualitative assessment of spasticity. However, many controversies exist about its validity in clinical practice.

In this study, we studied H-reflex responses (H latency and Hmax/Mmax amplitude ratios) in children with different degrees of spasticity (MAS scores). We found a positive correlation between Hmax/Mmax ratios and MAS. H latencies were found to be shorter and Hmax/Mmax amplitude ratios were higher in children with spasticity than in healthy controls.

The ratio of Hmax to Mmax waves (Hmax/Mmax amplitude ratio) is commonly used as an index of peripheral reflex excitability[16]. The Hmax/Mmax amplitude ratio may be equivalent to unity in normal subjects and may be increased in disorders causing spasticity, although it correlates poorly with the degree of spasticity noted clinically[17]. The Hmax/Mmax amplitude ratio is normal in cases of rigidity. Here, we found a slight, but statistically significant correlation between Hmax/Mmax amplitude ratios and MAS scores.

Hoffmann himself described H-reflex responses in 1973. Many aspects of this test have been studied in children with spatic forms of cerebral palsy, including changes in the response according to the state of alertness, to voluntary and automatic movement versus rest, pharmacological agents, and neurosurgical treatment, etc. A relevant relationship between H-reflex data and Ashworth scale was also noted previously, though conflicting results have been reported[7,18]. Kohan et al.[19] studied H-reflex and the ratio of maximum range of action potential of combined movement of the flexor carpi radialis for the upper limb and soleus for the lower limb in a small study group including 11 patients with an age range of 4 to 6 years. They reported that there was no significant correlation between degree of spasticity and H-reflexes.

The comparison of H latencies and MAS scores revealed that the relationship between Groups I and II was statistically significant. The relationships between Groups I and III and between Groups II and III were not statistically significant. Although patients with MASs of 4 (i.e., with contractures) were not included in the study, minimal contractures and decreases in muscle viscoelasticity were included in Ashworth scores. This finding was supported by the statistically significant difference in H latencies between Groups I and II but not between Groups I and III.

These results lead to the development of two ideas. First, a comparison of H-reflex and MAS revealed that H-reflex was found to be a valuable tool for measuring alpha neuron excitability, which leads to spasticity in cases where spasticity is mild according to the MAS. However, the value of H-reflex in this capacity decreases as spasticity increases due to the development of minor contractures, viscoelasticity and increases in alpha motor excitability. Second, this study's demonstration of the relationship between the MAS and H-reflex shows the possible utility and practicality of the MAS in clinical follow-ups of spasticity, as proposed by Bakheit et al.[7].

Electrophysiological tests have been used for evaluation of spasticity in humans. The F-wave, one of the tests used to measure spasticity, is evoked by antidromic reactivation ("backfiring") of motoneurons and is sensitive to changes in motoneuron excitability[10,20,21]. Delwaide[22] reported its potential usefulness and limitations in spastic patients. Two recent studies reported the clinical use of motor evoked responses obtained with transcranial magnetic stimulation in patients with spasticity[23,24]. However, all these tests have some limitations for the direct measurement of central spasticity in children.

In conclusion, we showed that decreases in H latency and increases in Hmax/Mmax ratios have a correlation with increases in spasticity. Therefore, we propose that H-reflex responses can be used to obtain objective data for evaluation of the treatment of spasticity in children.

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