Association between the Tones of the Ankle Plantar Flexors and Duration of Illness in Patients with Cerebrovascular Disease

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Abstract. [Purpose] The aim of this study was to clarify the association between the muscle tone of the ankle plantar flexors and duration of illness in patients with cerebrovascular disease (CVD). [Subjects] Seventy-four patients with CVD were the subjects of this study. [Methods] The tone of the ankle plantar flexors on the paretic side was measured in terms of the stretch reflex (SR), middle range resistance (MR), and final range resistance (FR) of the ankle plantar flexors tone scale (APTS). All APTS parameters were measured in 2 limb positions with the knee extended and flexed. The subjects were classified according to the duration of illness after onset into short- (<180 days) and long-term (≥180 days) groups. The associations between the duration of illness and SR, MR, and FR were analyzed. [Results] In the short-term group, SR was weakly correlated with the duration of illness in both the knee extended and flexed positions. However, in the long-term group, there was no association between the SR and duration of illness in either position. [Conclusion] The results of this study suggested an increase in the stretch reflex of the gastrocnemius muscle in the patients with a duration of illness <180 days.

Key words: Muscle tone, Duration of illness, Cerebrovascular disease

INTRODUCTION

Muscle hypertonia occurring in upper motor neuron lesions such as cerebrovascular disease (CVD) mainly induces spasticity. The basic mechanism of spasticity is an exaggerated stretch reflex resulting from interruption of descending inhibitory systems by upper motor neuron lesions. Therefore, spasticity is considered to be velocity-dependent muscle hypertonia (1-3). The central component is formed on muscle contraction by a stretch reflex. Based on this, spasticity comprises the central component of muscle hypertonia. However, in recent years, the peripheral component of muscle hypertonia has been reported to be also important (4, 5). The peripheral component is formed according to the muscle extensibility of soft tissues such as muscle fibers and fascia. In the approach to muscle hypertonia due to cerebrovascular disease, both the central component, as a hyperactive stretch reflex, and peripheral component, which consists of such things as decreased extensibility and shortening of muscle fibers and fascia, are important (6).

In patients with CVD, hypertonia of ankle plantar flexors, which markedly affects various activities, is an important target for rehabilitation. Hypertonia of the ankle plantar flexors sometimes induces ankle clonus, and these flexors are characterized by the mixture of mono- and biarticular muscles. Therefore, in the rehabilitation approach, the tone of the ankle plantar flexors should be evaluated in detail. There are various parameters of spasticity. Clinically, ordinal scales represented by the modified Ashworth scale (MAS) are widely used for their straightforwardness. Concerning the disadvantages of the MAS, the velocity and range of passive movement are not specified, and separate evaluation of the central and peripheral components is impossible (6). For such reasons, our research group has performed various studies to develop evaluation parameters and therapeutic approaches for hypertonia of the ankle plantar flexors due to CVD (6-11).

We previously developed a scale allowing evaluation separately for the central and peripheral components of the tone of the ankle plantar flexors (ankle plantar flexors tone scale: APTS), and evaluated its reliability and validity (6). The APTS consists of the following 3 items: the stretch reflex (SR) reflecting the central component, and the middle range resistance (MR) and final range resistance (FR) reflecting the peripheral component. Each item is measured using passive movement, and no special measurement system is necessary. Using a 5-grade ordinal scale (grade 0–4), muscle tone can be readily evaluated (6, 7).

As described above, muscle hypertonia due to upper motor neuron lesions consists of the central and peripheral components. Early after onset, hypertonia due to a hyperactive stretch reflex develops, and its persistence reduces...
the extensibility of muscle fibers and fascia, forming a peripheral component. Thus, with time after onset, changes in the components of the muscle tone may occur. There have been many studies on recovery in motor function and ability with time after onset\textsuperscript{12, 13)} but few studies on the association between muscle tone and the time after onset\textsuperscript{14}). Newman\textsuperscript{14)} reported changes in spasticity after onset of cerebral infarction, but did not separately evaluate the central and peripheral components.

With such a background, more detailed studies on the association between the tone of the ankle plantar flexors and the duration of illness are necessary. The purpose of this study was to clarify the association between the tone of the ankle plantar flexors and duration of illness by separately evaluating the central and peripheral components in patients with CVD.

**SUBJECTS AND METHODS**

**Subjects**

Table 1 shows the characteristics of the subjects. The subjects consisted of 74 patients with CVD (mean age, 77.5 ± 10.0 years; range, 48–92 years). All subjects were inpatients receiving rehabilitation in Honjo General Hospital. The subject inclusion criteria were as follows: the subjects were inpatients with hemiplegia due to CVD; rehabilitation had already been initiated; and informed consent for this study was obtained. The exclusion criteria were as follows: surgical treatment for hypertonia had been performed; the subjects were using anti-spasticity agents; the subjects developed pain during muscle tone measurement, affecting measurement results; and the limb positions for measurement could not be maintained for some reason. All measurements were performed by a physical therapist with 7 years of experience. As an assistant, another physical therapist with 7 years of experience maintained the limb position during measurement.

The subjects were classified into patients with a duration of illness < 180 days (short-term group) and those with a duration of illness ≥ 180 days (long-term group). All subjects in both groups received a routine physical therapy program that contained stretching for the ankle plantar flexors. Newman\textsuperscript{15)} reported that the degree of spasticity in patients with CVD rapidly increased between 4 and 7 weeks after onset and continued to increase until 20 weeks after onset. Andrew et al.\textsuperscript{13)} described that recovery of transfer activities and other activities of daily living cannot be expected 6 months or more after onset. Jorgensen et al.\textsuperscript{13)} reported that the recovery of activities of daily living was completed within 3 months after onset in 95% of the patients and within 5 months even in patients with severe disease. Changes in spasticity and the functional recovery period shown by previous studies vary, but recovery was completed within 6 months in most studies. Based on these studies, we classified the subjects of this study into two groups with a duration of illness < 6 months (180 days) or ≥ 6 months.

**Methods**

The tone of the ankle plantar flexors on the paretic side was measured in terms of the SR, MR, and FR of the APTS. The APTS is shown in the Appendix. The SR was measured while the muscle was stretched as fast as possible. The MR and FR were measured while the muscle was stretched as slowly as possible. All measurements involved movement from maximum plantar flexion to maximum dorsiflexion of the ankle. For evaluation with consideration given to mono- and biarticular muscles, measurement was performed in 2 limb positions with the knee completely extended or flexed at 90\degree. As a general rule, the knee extended position refers to knee extension at 0\degree. However, if the knee position at 0\degree could not be maintain for any reason, measurement was performed in the completely extended position for the subject. The SR, MR, and FR were measured 3 times each, and the maximum value was recorded. At the time of the development of the APTS, the reliability of the APTS was analyzed using the Cohen kappa coefficient (κ), and high reliability was confirmed (κ = 0.63–0.94)\textsuperscript{6). All measurements were performed in the supine position for the two limb positions with the knee completely extended or flexed at 90\degree. The day of disease onset was regarded as the first day, and the number of days until the measurement day was defined as the duration of illness.

**Table 1. Subject characteristics**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Subjects (n=74)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>77.5 ± 10.0</td>
</tr>
<tr>
<td>Sex (men/women)</td>
<td>31/43</td>
</tr>
<tr>
<td>Duration of illness (d)</td>
<td>1084.2 ± 2103.2</td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
</tr>
<tr>
<td>Cerebral infarction</td>
<td>56</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>12</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>6</td>
</tr>
<tr>
<td>Paretic side (right/left)</td>
<td>32/42</td>
</tr>
<tr>
<td>Brunnstrom stage of lower extremity paretic side (I/II/III/IV/VI)</td>
<td>1/15/22/19/11/6</td>
</tr>
</tbody>
</table>

NOTE: Values are either numbers or means ± SD.
Differences in age, sex, the duration of illness, diagnosis, paretic side, Brunnstrom stage of the lower extremity paretic side, SR, MR, and FR between the two groups were evaluated. The unpaired t-test was used for age and the duration of illness, the χ² test was used for sex, diagnosis, and the paretic side, and the Mann-Whitney U test was used for the Brunnstrom stage, SR, MR, and FR. In each group, the association between the duration of illness and SR, MR, or FR was analyzed using the Spearman rank correlation coefficient (r<sub>s</sub>). Correlation coefficients were interpreted as follows: 0–0.25, little if any correlation; 0.26–0.49, low (weak); 0.5–0.69, moderate; 0.7–0.89, high; and 0.9–1, very high.<sup>15</sup> These statistical analyses were performed for the knee extended and flexed positions. For all analysis, SPSS 17.0 J<sup>a</sup> for Windows was used, and p<0.05 was regarded as significant.

This study was performed with the approval of the Honjo General Hospital Ethics Committee (Approval No. 20080119). After an explanation of the purpose and methods of this study, written consent was obtained from all subjects.

**RESULTS**

Table 2 shows the subjects’ characteristics and results of APTS measurement. No subject fulfilled any of the exclusion criteria.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Short-term group (n=39)</th>
<th>Long-term group (n=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>77.7 ± 9.3</td>
<td>77.3 ± 10.8</td>
</tr>
<tr>
<td>Sex (men/women)</td>
<td>15/24</td>
<td>16/19</td>
</tr>
<tr>
<td>Duration of illness (d)</td>
<td>59.4 ± 44.9</td>
<td>2216.7 ± 2643.3</td>
</tr>
<tr>
<td>Diagnosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cerebral infarction</td>
<td>30</td>
<td>26</td>
</tr>
<tr>
<td>Intracerebral hemorrhage</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Paretic side (right/left)</td>
<td>16/23</td>
<td>16/19</td>
</tr>
<tr>
<td>Brunnstrom stage of paretic lower extremity (I/II/III/IV/V/VI)</td>
<td>0/8/11/9/8/3</td>
<td>1/7/11/10/3/3</td>
</tr>
<tr>
<td>APTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ext</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR (0/1/2/3/4)</td>
<td>13/8/11/1/6</td>
<td>19/9/4/0/3</td>
</tr>
<tr>
<td>MR(0/1/2/3/4)</td>
<td>2/18/15/3/1</td>
<td>10/14/7/3/1</td>
</tr>
<tr>
<td>FR(0/1/2/3/4)</td>
<td>0/8/19/11/1</td>
<td>3/8/13/10/1</td>
</tr>
<tr>
<td>Flex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SR(0/1/2/3/4)</td>
<td>13/7/9/5/5</td>
<td>15/4/11/1/4</td>
</tr>
<tr>
<td>MR(0/1/2/3/4)</td>
<td>12/19/8/0/0</td>
<td>19/12/2/2/0</td>
</tr>
<tr>
<td>FR(0/1/2/3/4)</td>
<td>2/22/11/4/0</td>
<td>7/14/5/9/0</td>
</tr>
</tbody>
</table>

NOTE: Values are either numbers or means ± SD. *p<0.05; **p<0.01, Abbreviations: APTS, ankle plantar flexors tone scale; SR, stretch reflex; MR, middle range resistance; FR, final range resistance; Ext, knee extended position; Flex, knee flexed position

Table 2. Subjects’ characteristics and APTS in the short- and long-term groups

In the knee extended position, the SR and MR were significantly higher in the short-term group than in the long-term group (p<0.05). In the knee extended position, the FR did not significantly differ between the two groups. In the knee flexed position, no significant difference was observed in the SR, MR, or FR between the short-term and long-term groups.

In the short-term group, the SR was weakly correlated with the duration of illness in both the knee extended and flexed positions (r<sub>s</sub> = 0.44–0.49, p<0.01). However, in the long-term group, there was no association between the SR and duration of illness in the knee extended or flexed position (r<sub>s</sub> = −0.14 − 0.07, p>0.05). In either group, there was no association between the MR or FR and the duration of illness (r<sub>s</sub> = −0.02–0.18, p>0.05) (Table 3).

**DISCUSSION**

The SR in the knee extended position was significantly higher in the short-term group than in the long-term group. However, the SR in the knee flexed position did not significantly differ between the two groups. In addition, in the short-term group, there was a weak positive correlation between the SR and duration of illness. These results suggested an increase in the stretch reflex of biarticular muscles involved in ankle plantar flexion in the patients with a duration of illness < 180 days compared with those with a duration of illness ≥ 180 days but no difference in the stretch reflex of monoarticular muscles. On the other hand, the
Multiple muscles are involved in ankle plantar flexion, including the triceps surae, peroneus longus, peroneus brevis, posterior tibial, and plantar muscles. The triceps surae muscle consists of the gastrocnemius and soleus muscles. Concerning the ankle plantar flexion force, 43% of it was exerted by the gastrocnemius muscle, and 37% was exerted by the soleus muscle. Since the two muscles exert 80% of the force, they may be closely involved in muscle hypertonia. The gastrocnemius muscle is a biarticular muscle acting on the knee and ankle, while the soleus muscle is a monoarticular muscle acting only on the ankle.

In the APTS, muscle tone was measured with the knee extended and flexed. When the ankle is dorsiflexed in the knee extended position, the gastrocnemius and soleus muscles are stretched. When the ankle is dorsiflexed in the knee flexed position, the soleus muscle is mainly stretched. Therefore, the results of measurement in the knee extended position mainly reflect the tones of the gastrocnemius and soleus muscles while those in the knee flexed position mainly reflect the tone of the soleus muscle. For example, when muscle hypertonia is observed in the knee extended position but decreases in the knee flexed position, hypertonia of mainly biarticular muscles can be considered. In this study, the SR and MR in the knee extended position were significantly higher in the short-term group than in the long-term group but did not significantly differ in the knee flexed position. The association between the degree of stretch reflex, as the central component, or resistance in the middle range of muscle stretching, as the peripheral component, and the duration of illness may be stronger for biarticular muscles (mainly the gastrocnemius muscle) than for monoarticular muscles (mainly the soleus muscle).

In this study, the association between muscle tone and duration of illness was cross-sectionally evaluated. To evaluate changes in the muscle tone with time from immediately after onset, a longitudinal study in which the time course of the muscle tone is evaluated is necessary. In patients with excessive spasticity or severe motor paralysis, muscle shortening occurs a long time after onset, sometimes reducing maximum muscle stretching. The APTS is a clinically useful scale allowing evaluation of muscle tone separately in terms of the central and peripheral components. However, the APTS does not allow measurement of the degree of maximum stretching. The FR represents resistance in the final range of muscle stretching and does not reflect the degree of muscle stretching. It may be also useful to clarify the association between the degree of muscle stretching and...
duration of illness. These points are limitations of this study. In this study, based on differences in the knee extended and flexed positions, evaluation with consideration given to bi- and monoarticular muscles was performed. This is a useful method using anatomical and kinematical characteristics. However, evaluation with strict separation between bi- and monoarticular muscles is difficult using only different limb positions. This is also a limitation of this study.

REFERENCES

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APPENDIX. THE ANKLE PLANTAR FLEXORS TONE SCALE

Points of note

- All tests are measured by passive dorsiflexion from the position of maximum plantarflexion to position of maximum dorsiflexion.
- All tests are performed three times, and the highest score is recorded.
- Results of measurement are compared with the nonparetic side in the case of hemiplegia.
- "Stretch reflex (SR)" measures neurological muscle reaction to passive movement.
- "Middle range resistance (MR)" measures resistance with passive movement, not including resistance of the final range.
- "Final range resistance (FR)" measures the resistance necessary to maintain the final position (i.e., excluding middle range resistance).

Velocity of passive dorsiflexion

- Stretch reflex (SR): As fast as possible.
- Middle range resistance (MR): As slow as possible
- Final range resistance (FR): As slow as possible

Position of measurement

- All measurements are given for knee extended and knee flexed at 90° in a supine position.
- The beginning position for passive movement is the position of maximum ankle plantarflexion.
- When this method is difficult, the rater must record the difficulty.

Scoring

- Stretch reflex (SR)
  0: No twitch
  1: Twitch and no clonus
  2: Mild clonus, persisting <3 s
  3: Moderate clonus, persisting 3–10 s
  4: Severe clonus, persisting >10 s
  - Middle range resistance (MR)
    0: No resistance
    1: Mild resistance, slight increase in resistance
    2: Moderate resistance, greater increase in resistance
    3: Severe resistance, considerable increase in resistance, but able to achieve passive movement
    4: Passive movement is difficult
    - Final range resistance (FR)
      0: No resistance
      1: Mild resistance, slight increase in resistance
      2: Moderate resistance, greater increase in resistance
      3: Severe resistance, considerable increase in resistance, but able to maintain final position
      4: Unable to maintain final position or passive movement is difficult