RELATIONSHIP BETWEEN HEMIPARETIC UPPER LIMB MOTOR FUNCTION AND MEDIAN NERVE SOMATOSENSORY EVOKED POTENTIAL AMONG CHRONIC STROKE SURVIVORS

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Abstract
The afferent input following stroke has an important role in motor relearning. The purpose of this study is to describe the relationship between upper limb clinical motor function and the status of the afferent system among chronic stroke survivors. Twenty-four chronic stroke survivors participated in the study. Clinical motor function of the paretic arm was assessed with the upper extremity portion of the Fugl-Meyer Motor Assessment (FMA). All subjects also underwent somatosensory evoked potential (SSEP) assessments of both median nerves. The FMA total scores were significantly correlated with the amplitudes of SSEPs (r = .68; p = .008). Data suggest a significant relationship between the status of the afferent system and clinical motor function among chronic stroke survivors.

Introduction/Background
Loss of motor function is a common and devastating outcome of stroke. The recovery from motor deficit from stroke can occur with functional reorganization of sensorimotor cortex.5 Motor control represents a complex interplay between afferent and efferent systems.7 Several studies suggest that the afferent system has an important role in both motor learning and motor recovery. The examination of the sensorimotor cortex of proficient Braille readers demonstrated expansion of the motor map of the reading hand, but also of the somatosensory map.6 An animal study revealed that ablation of a portion of the sensory cortex representing a given digit causes the intact adjacent sensory cortex to begin receiving input from that digit.7 These findings are consistent with the clinical observation that stroke survivors with only motor impairment experience significantly greater functional recovery than those who have both motor and sensory deficits.8

The measurement of somatosensory evoked potentials (SSEPs) is a valid and objective method of assessing the integrity of afferent pathway of central nervous system.1 SSEPs are good predictors of clinical motor recovery following stroke.4 Abnormal median nerve SSEP studies predict poor upper extremity function during stroke rehabilitation.10 Pavot et al7 also showed that SSEP results divided into four grades were significant predictors of functional outcome.

Although these earlier studies suggest that SSEP results can be used as prognostic factors for future motor recovery, it is unclear whether it can be used as a measure of central neuroplasticity with respect to motor recovery. Prior to utilizing SSEP as an outcome measure for motor recovery, the validity of SSEP reflecting concurrent clinical motor function must be demonstrated. Thus, the purpose of this study is to elucidate the relationship between median nerve SSEP parameters and concurrent clinical motor function of the hemiparetic upper limb among chronic stroke survivors.

Methods
Twenty-four chronic stroke survivors who are beyond 6 months from their first nonhemorrhagic or hemorrhagic stroke were included in this study. All subjects were medically stable. Subjects with ipsilateral upper extremity lower motoneuron lesion, or other upper motoneuron lesion such as spinal cord injury, traumatic brain injury, and multiple sclerosis were excluded. The study protocol was reviewed and approved by the human subjects committee.

Motor function was assessed using the upper extremity score of the Fugl-Meyer Motor Assessment (FMA).2 The items in the motor subsections were derived from Brunnström’s stages of poststroke motor recovery, although the specific stages were not used. The data arise from a 3-point ordinal scale: 0, unable to perform the function; 1, partial performance; 2, complete performance.

For the evaluation of afferent system, median nerve SSEP studies were performed bilaterally on the same day as the FMA. Four electrodes were placed over each hemisphere to account for possible changes in the
The first surface electrode was positioned on the contralateral somatosensory area (C3’/C4’) on the 10-20 International System (position B). Two additional electrodes were placed 2 cm (position C) and 4 cm (position D) lateral to position B. An additional electrode was placed 2 cm medial to position B (position A). A surface electrode was placed over the C2 vertebra. The reference electrode was placed at Fz. Each median nerve was stimulated independently with a 0.1 msec width pulse at a rate of 4.39 Hz. At least two trials were performed to ensure the reproducibility of the evoked response. The evoked potentials were obtained by averaging the recordings after 400 stimuli or more. The absolute latencies for N1 and P1 and the peak-to-peak amplitude of the N1/P1 were determined. In order to minimize intersubject variability, an interhemispheric ratio of N1/P1 amplitude was calculated, as the measure for analysis. Responses were filtered through a bandpass of 10 to 1,000 Hz. Impedance of all electrodes was less than 5,000 Ohms.

The relationship between FMA and SSEP parameters was explored. FMA parameters included the proximal and distal subscores and the total score. SSEP parameters included absolute amplitude and onset latency and normalized amplitude. FMA scores of subjects with SSEP waveforms were statistically compared to those with absent waveform by means of Mann-Whitney U test. Spearman’s correlation coefficients were generated to describe the relationship between FMA scores and SSEP data.

Results

The mean age of subjects was 50.21 years (SD 13.14) with a range of 22 to 82. There were 14 men and 10 women. The mean time interval after the occurrence of stroke was 40.7 months (SD 28.0). The cause of stroke was ischemic in 16 subjects, hemorrhagic in 8 subjects. Upper extremity motor score of FMA varied between 4 and 62 with a mean of 38.74 (SD 20.23).

Fourteen subjects showed a significant SSEP waveform on the affected side. Ten subjects had absent response on the affected side. The characteristics of the 2 groups are shown in Table 1. Subjects who had significant waveforms on the affected side exhibited significantly higher FMA score compared to those without significant waveforms (median: 43 versus 22; U = 15.5; W = 60.5; Z = -.30; p = .003).

Among subjects with significant SSEP waveforms, normalized N1/P1 amplitude was significantly correlated with FMA score (Table 2). Correlation of total score of upper extremity FMA with normalized SSEP amplitude was significant for all recording sites. Similarly, coordination subscore of FMA was significantly correlated with normalized SSEP amplitude for all recording sites. Proximal FMA subscore was significantly correlated with normalized SSEP amplitude at positions C and D, but not at position A or B. The hand and wrist FMA subscores were not correlated with normalized SSEP amplitude.

The absolute latencies of N1 and P1 and absolute peak-to-peak amplitude of the N1/P1 were not significantly correlated with FMA score.

Table 1. Characteristics of the Subjects According to Presence of SSEP Waveform on the Affected Side

<table>
<thead>
<tr>
<th>Waveform</th>
<th>Age (years)</th>
<th>Onset to Assessment interval (months)</th>
<th>Ischemic stroke (%)</th>
<th>Cortical stroke (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No waveform</td>
<td>52.2 ± 16.3</td>
<td>43.2 ± 28.6</td>
<td>71.4</td>
<td>35.7</td>
</tr>
<tr>
<td>No waveform</td>
<td>47.4 ± 6.4</td>
<td>37.2 ± 28.3</td>
<td>60.0</td>
<td>60.0</td>
</tr>
</tbody>
</table>

Table 2. Correlation Coefficients between FMA Subscores of Upper Extremity and Normalized Amplitude at Different Recording Sites

<table>
<thead>
<tr>
<th>Electrode positions</th>
<th>FMA†</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proximal</td>
<td>.52</td>
<td>.46</td>
<td>.64*</td>
<td>.66*</td>
<td></td>
</tr>
<tr>
<td>Wrist</td>
<td>.16</td>
<td>.23</td>
<td>.38</td>
<td>.49</td>
<td></td>
</tr>
<tr>
<td>Hand</td>
<td>.14</td>
<td>.23</td>
<td>.39</td>
<td>.48</td>
<td></td>
</tr>
<tr>
<td>Coord‡</td>
<td>.67**</td>
<td>.58*</td>
<td>.65*</td>
<td>.70**</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>.56*</td>
<td>.54*</td>
<td>.65*</td>
<td>.68**</td>
<td></td>
</tr>
</tbody>
</table>

†Fugl-Meyer Motor Assessment
‡Coordination subscore; *p < .05; **p < .01
A, 2 cm medial to B; B, C3’/C4’; C, 2 cm lateral to B; D, 4 cm lateral to B

Discussion/Conclusions

The major finding of this study is that there is a statistical relationship between motor function and normalized SSEP amplitude. This relationship is likely due to the fact patients with more severe motor impairments often have larger strokes involving cortical structures and effect multiple modalities including sensation. Thus, it is possible during natural recovery that with improvement in one modality such as motor ability, there is a concomitant improvement in other modalities such as sensation. It is also possible that in view of the likely importance of afferent feedback in motor relearning, patients with intact sensation simply experience greater motor recovery than those with impaired sensation. While the demonstration of a
statistical relationship between motor impairment and SSEP parameters is an important prerequisite for using SSEP as an outcome measure of central motor function, it remains unclear whether improvements in motor function due to a specific intervention will lead to meaningful changes in SSEP parameters. This will need to be demonstrated in future studies.

We elected to use a multiple electrode array to record SSEP waveforms in order to account for possible reorganization of the somatosensory cortex due to stroke. An interesting finding is that FMA scores tended to correlate best with SSEPs recorded from the lateral most electrodes. One possible explanation is that the hand representation is positioned laterally in the somatosensory cortex. Due to insufficient power of the study and narrow range of scores, the hand and wrist FMA scores did not correlate significantly with SSEP parameters. However, the difference in correlation coefficients across electrode positions is even more remarkable with waveforms recorded from lateral electrodes having the highest correlation coefficients. The proximal FMA scores correlated well with SSEP parameters because proximal motor function correlates well with distal motor function (r = .75 for proximal FMA versus hand and wrist FMA; p < .001) and the range of proximal FMA scores are higher.

In conclusion, data demonstrate that clinical upper limb motor function after stroke and median nerve SSEP amplitudes are statistically related. Data further suggest that recordings from electrodes placed lateral to the traditional C3’/C4’ location is more specific to upper limb motor function.

References

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