Physiologic Decrease of Single Thenar Motor Units in the F-Response in Stroke Patients

Yukihiro Hara, MD, DMSc, Kazuto Akaboshi, MD, DMSc, Yoshihisa Masakado, MD, DMSc, Naotchi Chino, MD, DMSc


Objective: To investigate the left-right difference and the reproducibility by the F-wave motor unit number estimation and to compare the motor unit number between the hemiplegic and unaffected side in stroke patients.

Setting: A referral center and institutional practice providing outpatient care.

Subjects: Seven healthy volunteers and 15 consecutive stroke patients.

Design: Diagnostic statistical test and correlational study.

Method: Submaximal stimuli were used to evoke a sample of surface motor unit action potentials (S-MUAPs) in the F-waves that are entirely representative of the relative numbers of detected S-MUAPs of different sizes. The average S-MUAP amplitude was calculated from a selected population of F-wave responses for each abductor pollicis brevis (APB) muscle. The motor unit number was calculated by dividing the maximum M-potential negative peak amplitude by the average S-MUAP negative peak amplitude.

Result: There was no statistical difference between motor unit numbers on either side and between test and retest in this motor unit number estimation method among normal subjects. The motor unit number on the hemiplegic side was significantly lower than on the unaffected side (p < .05, Mann-Whitney test) among stroke patients.

Conclusion: The motor unit could decrease in the hemiplegic side after a moderate-to-severe hemiplegic stroke and this decrement might be due to the transsynaptic degeneration secondary to an upper motor neuron lesion.

Key Words: Stroke; Motor unit; Electromyography; F-wave.
© 2000 by the American Congress of Rehabilitation Medicine and the American Academy of Physical Medicine and Rehabilitation

Several published investigations have shown that pathological spontaneous activity can occur in electromyographic studies in upper motor neuron (UMN) lesions, for example from stroke and spinal cord injury (SCI).1-5 Benecke and colleagues5 reported that pathological spontaneous activity could be observed in selected stroke patients in whom peripheral nerve lesions were excluded by an extensive clinical and electrophysiologic examination. There may be some impairment and deficit in anterior horn cells among stroke patients.6 But few studies have been reported regarding the electrophysiologic motor unit counting in stroke patients.7 There are some practical methods for estimating the number of motor units in a muscle.8,9 For example, the F-wave method measures the F-wave responses of one or more motor units in response to weak electrical stimulation of a motor nerve.10 F-wave studies in clinical use generally adopt supramaximal stimulation to elicit F-responses. Recent work, however, has shown that submaximal stimuli can evoke a sample of surface motor unit action potentials (S-MUAPs) in the F-response entirely representative of the relative numbers of S-MUAPs of different sizes generated in the thenar muscles even by 10% to 30% of the stimulus intensities that evoke the maximum M-potential.10-12

A protocol, consisting of a series of algorithms, was developed to obtain a maximum M-potential, collect a population of F-waves representing S-MUAPs, and calculate average S-MUAP waveforms to estimate the number of motor units in a muscle.11 First, we studied the reproducibility of, and the left-right difference in, the motor unit number estimation (MUNE) by the F-wave method. Second, we compared the electrophysiologic motor unit counting numbers from both the hemiplegic and unaffected sides among stroke patients.

SUBJECTS

Seven healthy volunteers were examined to study the left-right differences and reproducibility of the F-wave method for MUNE. The four men and three women ranged in age from 28 to 39 years (mean = 31.3). Fifteen consecutive stroke patients (13 men, 2 women) with unilateral lesion as the first episode were examined after giving informed consent. Their mean age was 64.2 ± 8.6 years. Eight had had a cerebral infarction; seven had a cerebral hemorrhage. Seven patients had cerebral lesions on the right side and eight patients had cerebral lesions on the left side. The duration of hemiparesis ranged from 66 to 227 days (x = 136.6 days). All patients had moderate to severe spastic hemiplegia with Brunstrom stages ranging from 1 to 3 in upper extremity (U/E) and finger (F) paresis. Their Brunstrom stage distribution was Stage 1 (no activation of the limb): U/E 4, F 6, Stage 2 (spasticity appears, and weak basic flexor and extensor synergies are present): U/E 3, F 2, Stage 3 (spasticity is prominent; the patient voluntarily moves the limb, but muscle activation is all within the synergy patterns): U/E 8, F 7. The exclusion criteria were cervical spondylosis, diabetes mellitus, and other diseases that might affect the peripheral nerves or peripheral neuropathy by history, neurologic examination, and electrodiagnostic test.
METHODS

For the MUNE, the modified F-wave method was applied to the median innervated thenar muscle according to the MUNE method as introduced by several researchers. Ag-AgCl surface electrodes (1.1cm diameter) were used. The active electrode was positioned over the close proximity to innervating zone (anatomical midpoint of the muscle) of the abductor pollicis brevis (APB) muscle and the reference electrode was positioned over the metacarpal phalangeal (MP) joint of the thumb. A large ground reference electrode was positioned between the stimulus and detection sides. The maximum M-potential was evoked by supramaximal stimulation of the median nerve at the wrist and elbow with a Dantec electromyographic machine (Counter Point®). The detected signals were captured and displayed with a band pass of 2.0Hz to 2kHz. The stimulation frequency was 1Hz and duration was 200 milliseconds. We used the F-wave program in the electromyography (EMG) machine to collect the single S-MUAPs.

The stimulus current intensity was initiated from very low level and F-wave was not evoked initially. The stimulus current intensity was adjusted to evoke M-potentials with about 10% to 20% of peak-to-peak amplitude of the maximum M-potential. Then, the intensity was gradually increased to the level at which the reproducible, all-or-nothing F-wave was evoked. Once a satisfactory stimulus intensity was decided, the stimulation was continued at that intensity level. The latencies and sizes of any particular motor unit detected in such F-response remain remarkably stable from stimulus to stimulus. The F-wave groups of identical matches with two or more members were assumed to be single S-MUAP. The S-MUAPs consisted of F-wave groups of identical matches with the same latency, amplitude and shape (fig 1).

The maximum M-potentials and F-wave responses were saved on a computer hard disk connected to the EMG machine and were later analyzed for the MUNE. Extracted responses were then presented in a rastered display on a computer graphics screen. A F-response was required to be identical in shape, size, and latency on two or more occasions. To determine this, a candidate S-MUAP F-response was selected and, using the screen and printing, was individually visually compared with every other remaining response in the raster. Identical responses were grouped and removed from the list to be analyzed later and a new candidate S-MUAP was selected and compared in the same fashion. Candidate S-MUAPs with no matches were assumed to be either the compound sum of the F-responses of two or more S-MUAPs or single S-MUAPs that failed to repeat. In either case, these responses were removed from the raster and from further consideration. When all extracted responses had been grouped with identical matches or determined to be an unmatched candidate S-MUAP, groups of identical matches with two or more members were displayed and a typical S-MUAP was chosen from each group and stored for subsequent analysis.

The APB muscles on both sides were examined and compared in control subjects and stroke patients. The healthy volunteers had the same MUNE examination again about 1 week later to study reproducibility. Median nerve conduction velocity and minimum F-wave latency were also examined on both sides among the stroke patients. Their concentric needle EMG was simultaneously examined at the hemiplegic APB muscle.

Analysis

More than 10 representative single S-MUAPs were collected for the analysis among a population of more than 300 F-wave responses. The average S-MUAP negative peak amplitude was calculated from representative single S-MUAPs. The motor unit number was calculated by dividing the maximum M-potential negative peak amplitude by the average S-MUAP negative peak amplitude.
Statistics
Mean values are presented along with their standard deviations (SDS). The intraclass correlation coefficient was examined for reproducibility between the first and second trials among normal subjects. We compared the electrophysiologic motor unit counting numbers from the right and left sides among normal subjects. Among stroke patients, the hemiplegic-side motor unit number was compared with the unaffected side. The Mann-Whitney test was used to compare motor unit mean values from both sides among normal subjects and stroke patients. Significant differences were accepted at $p < .05$.

RESULTS
Figure 2 shows the M-response stimulated at the wrist and the S-MUAPs in F-waves in 62-year-old patients with left-sided hemiplegia. The MUNE was calculated as the maximum M-potential negative peak amplitude divided by the average S-MUAP negative peak amplitude.

Left-right differences among normal subjects. The mean motor unit number was 231.5 ± 39.5 for the right-side APB muscle and 227.9 ± 39.8 for the left-side APB muscle ($n = 14$). There was no statistically significant difference between APB motor unit numbers (fig 3) for both sides. This method showed no left-right difference in the motor unit number at the APB muscle among the normal subjects.

Reproducibility among normal subjects. The mean motor unit number was 238.1 ± 49.0 based on the first examination and 232.4 ± 32.8 based on the second examination ($n = 14$). There was no statistically significant difference between the first and the second estimated motor unit numbers among healthy volunteers (fig 4). The intraclass correlation coefficient was .815 between the first and second MUNE examinations of the same muscles. This result suggests good reproducibility using this F-wave MUNE method.

MUNE in stroke patients. Thirteen of 15 patients revealed the denervation potential (positive sharp wave or fibrillation potential) by the needle EMG at the hemiplegic APB muscles. The maximum M-potential negative wave amplitude on the hemiplegic side (6.61 ± 1.82mV) was significantly smaller than on the unaffected side (11.00 ± 3.62mV). However, the hemiplegic side (82.61 ± 28.62µV) showed larger mean S-MUAP negative amplitudes than the unaffected side (79.42 ± 28.57µV), and there was no significant difference between them (fig 5). There was also no statistically significant difference between hemiplegic and unaffected sides for median motor nerve conduction velocity (52.7 ± 6.7msec vs 57.8msec), median motor nerve distal latency (4.0 ± 0.6msec vs 3.9 ± 0.6msec), or median nerve minimum F-wave latency (27.7 ± 2.2msec vs 26.7 ± 2.1msec). Figure 6 displays the motor unit numbers in the APB muscles on the hemiplegic and unaffected sides. The mean motor unit number was 87.7 (SD 22.4) on the unaffected side and 141.9 (SD 37.1) on the hemiplegic side; the latter was significantly smaller than that of the unaffected side ($n = 15$, $p < .01$, Mann-Whitney test).

DISCUSSION
There are some electrophysiologic methods that enable approximate motor unit numbers to be obtained rapidly and easily. The F-wave method for MUNE by Stashuk and colleagues requires special software for computer analysis.
and uses the negative peak area for MUNE. The current study uses the negative amplitude for MUNE. The method adopted is a simple manual process, not requiring special computer analysis. We combined the methods of Doherty11 and Komori10 with the F-wave MUNE method. Alternation can cause calculation errors in electrophysiologic MUNE methods such as the incremental method.15 But the F-wave method, accepting only those responses that have been repeated more than twice,10 reduces alternation.

Doherty and Brown12 have reported that by using 10 S-MUAPs, the degree of variability in the average S-MUAP was substantially reduced, after which the average value remained relatively stable. For that reason, we collected at least 10 S-MUAPs for the motor unit measurement. Our experiment showed good reproducibility to some extent in healthy volunteers, as Stashuk and colleagues14 have reported, and no statistical difference between motor unit numbers in the same bilateral muscle. Collecting a larger number of S-MUAP samples may improve reproducibility. The averaged motor unit number among control subjects in our study have been similar with the MUNE reported by Doherty and Brown.12 We confirmed that our F-wave MUNE method could be applied for comparing motor unit numbers between the hemiplegic side and unaffected side in stroke patients.

The APB muscle was used for the motor unit counting, because it was easily stimulated electrically. In addition, it often reveals the pathological spontaneous activity of a needle EMG, which is seen in the distal muscles of a hemiplegic upper extremity.2,3,5

Several authors have reported that disuse might not be a major factor of muscle wasting in hemiplegic patients with stroke.8 There have been some reports that the decrease of hemiplegic side M-potential reflects the decrease of motor unit numbers.8,16 A number of authors have indicated that pathological spontaneous activity can occur in the EMG after strokes.1-5 Most of them have estimated that pathological spontaneous activity in hemiplegic muscles might be due to transsynaptic degeneration.4,5 However, there have been few reports that have shown the decrease of motor units in hemiplegic muscles.6,8

![Fig 4](image1.png)  
**Fig 4.** The reproducibility in motor unit numbers among healthy volunteers (n = 14). MUE T1, motor unit estimation, first trial; MUE T2, motor unit estimation, second trial.

![Fig 5](image2.png)  
**Fig 5.** The maximum M-response amplitudes and mean F-wave amplitudes (n = 15). The maximum M-potential negative amplitude in hemiplegic side was significantly smaller than in unaffected side (*p < .01; Mann-Whitney test). The hemiplegic side showed larger mean S-MUAP negative amplitudes than the unaffected side, but there was no significant difference between them.

![Fig 6](image3.png)  
**Fig 6.** The motor unit numbers in the hemiplegic and noninvolved side APB muscle (n = 15). The mean motor unit number in the hemiplegic side was significantly smaller than in the unaffected side (*p < .01, Mann-Whitney test).
Kondo and colleagues have reported that the degree of degeneration of the lateral corticospinal tracts seemed to parallel that of fiber loss in ventral roots among stroke patients. They assumed that a transsynaptic effect of the degenerated UMN (lateral corticospinal tract) in patients with cardiovascular disease facilitated fiber loss in the ventral roots. McComas has reported a motor unit decrease at the extensor digitorum brevis muscle on the hemiplegic side using McComa’s incremental method. Gorman and colleagues have reported that numbers of motor units in patients with SCI were significantly lower for the muscles innervated below the level of injury by the electrophysiologic method. They assumed that this motor unit decrement might be due to the transneuronal anterior horn cell degeneration. Our study also showed that the electrophysiologically estimated motor unit number, as measured by the F-wave MUNE method, decreased at the APB muscle on the moderate-to-severely involved hemiplegic side after stroke.

Slawnych and associates have reported that estimates obtained in normal muscle were generally higher than the actual number of motor units in the muscle and the estimates for neurogenic muscles have a much smaller error. Even if considering this variation, our results reflected the difference in motor unit numbers between hemiplegic and unaffected sides.

This motor unit decrement on the hemiplegic side might be due to the transsynaptic degeneration of alpha-motorneurons as a result of UMN involvement. According to this concept, the motorneurons may undergo degeneration from deprivation of trophic inputs, which they normally receive through descending motor pathways from UMs. Recent radiologic evidence by magnetic resonance imaging (MRI) studies suggest that wallerian degeneration (WD) of pyramidal tract occurs no earlier than 3 months after a subcortical infarction. Several stroke patients with motor unit decrement in our experiment also revealed WD by their MRI study. Increased signal intensity on T2-weighted images as seen in patients with WD might be due in part to increased water content secondary to gial proliferation. This WD of pyramidal tract might have some relation with the motor unit decrement in the hemiplegic side after stroke.

On the contrary, Qiu and Terao and their colleagues reported that there was no significant difference in morphometrical anterior horn cell number between the affected and unaffected sides in strokes. But transsectional areas of anterior horn cells associated with the hemispheric lesional side were significantly decreased compared with those of the unaffected sides in patients and normal subjects. Our data showed the motor unit decrement in the hemiplegic side by using an electrophysiologic method of measurement. The electrophysiologic MUNE value is for the number of “functional” motor units in the muscle, that is, the number of units, that can be excited by electrical stimulation. Terao and associates reported that although the left-right differences were not evident morphometrically, loss of trophic effect from UMs could alter the functional state of anterior horn cell in the affected side without loss of the cell itself. We assumed that the motor units may remain morphometrically unchanged in their number but the functional motor units number in the hemiplegic side might decrease among stroke patients.

The S-MUAP amplitude on the hemiplegic side was larger than on the unaffected side but there was no statistical significance. This suggests losses of motor neurons and the subsequent enlargement of the remaining motor units, with sprouting as reflected in increased mean S-MUAP sizes. Dattola and coworkers have suggested the trans-synaptic degeneration after stroke and muscle rearrangement morphologically. However, such sprouting may not be enough to cause statistically significant differences about 4 months after onset. We need to follow-up the MUNE in the same stroke patients longer to investigate the subsequent enlargement of the remaining motor units with sprouting.

CONCLUSION

There was no statistical difference between motor unit numbers on both sides in normal subjects by the F-wave method. In addition, the F-wave MUNE method revealed good reproducibility among them. The MUNE was performed by F-response method among stroke patients with moderate-to-severe hemiplegia. The motor unit number in the APB on the hemiplegic side was significantly lower than on the unaffected side, as measured electrophysiologically. The physiologic drop of motor units may be due to the transsynaptic degeneration of alpha-motorneurons because of the UMN lesion.

References


**Supplier**