Electrophysiological investigation of hemifacial spasm after microvascular decompression: F waves of the facial muscles, blink reflexes, and abnormal muscle responses

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Microvascular decompression (MVD) of the facial nerve near its exit from the brainstem has been established as an effective treatment of hemifacial spasm. However, at what point does hemifacial spasm disappear completely after MVD? It has been said that some patients with hemifacial spasm do not experience immediate complete relief after MVD. In these patients the spasm gradually disappears in 1 to several weeks or in 4 days to 22 months after MVD.

To date, there has been no electrophysiological investigation of patients with hemifacial spasm either during the period in which hemifacial spasm still remains after MVD or after it has disappeared completely.

Two hypotheses for the underlying electrophysiological mechanism of hemifacial spasm exist: 1) compression of the facial nerve by a blood vessel injures the myelin sheath and facilitates the ephaptic transmission between individual nerve fibers, thereby increasing spontaneous activity, or 2) the spasms are induced by hyperexcitability of the facial motor nucleus itself. In experimental studies, it has been shown that chronic stimulation of the facial nerve causes abnormal muscle responses (lateral spreads), which constitute a typical sign in hemifacial spasm that involves the facial motor nucleus.

Electrophysiological investigations have been performed in patients with hemifacial spasm and F waves have been recorded in facial muscles. The F waves are antidromically activated motor neurons of the facial motor nucleus, and are indices of the excitability of the facial motor nucleus and are enhanced in patients with hemifacial spasm. Measuring blink reflexes and abnormal muscle responses (lateral spread), a characteristic sign of hemifacial spasm, has been used to investigate the mechanism of hemifacial spasm pathophysiologically. Thus the authors measured F waves of the facial muscle, blink reflexes, and abnormal muscle responses before and after MVD in patients suffering from hemifacial spasm to investigate the excitability of the facial motor nucleus and the course of the cure of hemifacial spasm after MVD. The authors obtained facial nerve–evoked electromyograms in 20 patients with hemifacial spasm before and after the MVD procedure. On the spasm side, the F waves and blink reflexes were enhanced preoperatively compared to those on the normal side and abnormal muscle responses were recorded in all patients. In 12 patients whose hemifacial spasm had not disappeared completely for 5.1 ± 1.7 (mean ± standard error) months following the MVD procedure, F waves were still enhanced significantly and abnormal muscle responses were still recordable, albeit at lower amplitude. Within 1 month after the hemifacial spasm had disappeared completely, F waves were still significantly enhanced in 17 patients and abnormal muscle responses were recorded in seven of 15 patients. Subsequently, the enhanced F waves and abnormal muscle responses disappeared completely. The authors’ study supports the hypothesis that the cause of hemifacial spasm is hyperexcitability of the facial motor nucleus and suggests that additional surgery should not be performed for at least 2 years after MVD, because that period is necessary for the disappearance of the hyperexcitability of the facial motor nucleus.

Key Words • hemifacial spasm • F wave • lateral spread • microvascular decompression • surface electrode
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uate hyperexcitability of the facial motor nucleus in patients with hemifacial spasm by measuring the latency and duration of the R2 component, the R1 and R2 recovery curves. It has been shown in patients with hemifacial spasm that when one branch of the facial nerve is stimulated, an abnormal muscle response can be recorded from muscles innervated by other branches of the facial nerve.

In this study we measured the F waves of facial muscles, blink reflexes, and abnormal muscle responses after MVD surgery in cases in which hemifacial spasm was still seen, in cases in which the spasm disappeared immediately, and in cases in which the spasm disappeared completely after a while. We initiated this study to investigate the pathophysiology of hemifacial spasm and to examine the time period within which it disappears completely after MVD.

Clinical Material and Methods

Patient Population

We studied 20 patients who had no history of facial nerve block or paralysis, but who had a clinical diagnosis of cryptogenic hemifacial spasm, such as paroxysmal and repetitive involuntary hemifacial contractions of the muscles controlling facial expression. There were six men and 14 women in the group, ranging in age from 31 to 72 years (mean 52 years).

The F Waves of Facial Muscles

The patients lay in a relaxed position on a bed and were connected to the monitoring equipment. An unstable baseline was typically correlated with facial spasm. After the spasm disappeared, we began the examination. A flat baseline was obtained prior to stimulation (Fig. 1), and readings containing evidence of either random voluntary activity or involuntary activity were excluded. Stimulation was applied at the border of the mandible, 10 cm from the stylomastoid foramen. Stimulation was effected using a stick-type surface electrode (model NM-430S; Nihon Kohden, Tokyo, Japan) and was repeated 32 times using a 0.2-msec square wave at a frequency of 1 Hz. The stimulation strength was set at the highest level for the direct compound muscle action potential (M wave). To prevent overlap between the F wave and the M wave, the latency period of the F wave was lengthened as much as possible by stimulating the distal margin of the mandibular branch and by recording at the mentalis muscle; the M wave was shortened as much as possible using a 100-Hz low-pass filter. We were able to record the F waves of the facial muscle as far away as possible from the facial motor nucleus, that is to say, the mentalis muscle. It was impossible to record the F waves of the orbicular muscle of the eye because of overlapping between the F and M waves. The negative-recording surface electrode was located on the mentalis muscle and the positive-recording surface electrode was placed at the base of the mandible. The filter was set at a high cutoff of 2 kHz. The F waves, which varied with each stimulus and were not always elicited (Fig. 1), were analyzed for the F/M amplitude ratio (the percentage of the peak-to-peak amplitude of F wave to M wave), F wave duration (from the initial deflection from the baseline to the final return of the F wave) and the frequency of F-wave appearance (the percentage of 32 stimuli that produced F waves with a distinct peak and amplitude above 30 μV) as shown in a previous paper; the values of F/M amplitude ratios and F-wave durations were averaged in each case. These parameters are usually reported in the assessment of peripheral nerve F waves recorded with a surface electrode.

Abnormal Muscle Responses

We measured the abnormal muscle response (or so-called “lateral spread”) that appeared at the mentalis mus-
cle (zygomatic nerve stimulation) on the evoked facial myogram under the same conditions as the F wave. The zygomatic branch was stimulated at the lower edge of the zygomatic bone with a stick-type surface electrode. When the abnormal muscle response was not easily recorded or when the amplitude was small during and after MVD, the stimulation strength was increased to 20 mA. The abnormal muscle responses were analyzed to determine the abnormal muscle response/M-wave amplitude ratio (that is, the percentage of the peak-to-peak amplitude of the abnormal muscle response to the M wave).

**Blink Reflexes**

We measured only R2 responses (late homolateral component) and R2c responses (late contralateral component) of blink reflexes with paired stimuli at an interstimulus interval of 200 msec. Areas of the R2 and the R2c were calculated; R1 responses (early component) were not measured in this study. Pairs of surface electrodes were placed over the orbicular muscle of the eye on both sides (mid-lower eyelid and temple). The cathode of the stimulating electrode was placed at the supraorbital foramen and the anode was placed immediately above (on the forehead), using the stick-type surface electrode. The R2 ratio was obtained by measuring the percentage of R2c and R2 responses to a single stimulus and placing them in a ratio (R2c/R2). The recovery rate of the R2 area during an interstimulus interval of 200 msec was obtained by measuring the percentage of the R2 area response on the stimulated side elicited by the first and second stimuli and placing them in a ratio (second response/first response). Four trials were conducted and the areas of the responses were averaged (Fig. 2).

Stimulation was applied for all the evoked potentials when the muscles were electrically at rest, avoiding stimulation of the nerve during spasms. Before and after sur-

![Fig. 2. Recordings of blink reflex responses evoked by paired stimuli with an interstimulus interval of 200 msec in patients with hemifacial spasm before MVD. Areas of the R2 on the spasm side were larger than those on the normal side when stimulated on the spasm side or on the normal side. The R2 was evoked by the second stimulus more easily on the spasm side than on the normal side.](image)

![Fig. 3. Graphs displaying the ranges (mean ± standard deviation [SD]) of the F/M amplitude ratio (%), F-wave duration (msec), F-wave frequency (%), R2 ratio (R2c/R2), and recovery rate of R2 (second response/first response) in patients with hemifacial spasm before MVD. N = number of examined cases; open circle = mean ± SD.](image)
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Fig. 4. Graph displaying the abnormal muscle response (AMR)/M-wave amplitude (%). Before decomp. = before decompression under anesthesia; after decomp. = after decompression under anesthesia. Open circle = mean values in 16 patients; closed circle = mean values in seven patients whose abnormal muscle responses were recorded after decompression while the patients remained anesthetized. Dotted lines indicate the patients whose hemifacial spasm disappeared immediately after MVD.

Preoperative Assessment

The F Waves of Facial Muscles. The F waves followed the direct compound muscle action potential (M wave) (Fig. 1). Before and after these potentials, baselines were stable. The waveform of the F wave varied from trial to trial on both the normal and spasm sides and the F wave was not always elicited by every stimulus, just as in the case of the extremities.

The F/M amplitude ratio (p < 0.01) and the duration (p < 0.001) and frequency (p < 0.05) of F waves increased significantly on the spasm side compared to the normal side.

Blink Reflexes. The ratio (R2c/R2) that was calculated during stimulation of the spasm side was significantly decreased compared to that calculated during stimulation of the normal side (p < 0.001). The difference in the recovery rate of the R2 area between the spasm side and the normal side during an interstimulus interval of 200 msec was statistically significant (p < 0.05). On the normal side, R2 was elicited by the second stimulus in only one of seven patients. (When the R2 was not elicited by the second stimulus, we regarded this recovery rate as 0%.)

Abnormal Muscle Responses. On electromyography of the mentalis muscle (zygomatic facial nerve stimulation), the abnormal muscle response was present at approximately 10 msec in all 20 patients.

Operative Assessment

Although the abnormal muscle response was recorded at the end of surgery in seven of 16 patients, the abnormal muscle response/M-wave ratio decreased significantly compared to that assessed at the beginning of the operation after anesthesia had been induced in the patient (paired t-test, p < 0.001) (Fig. 4). (When the abnormal muscle response disappeared after MVD, we regarded the ratio as 0%.) Even in the seven patients whose abnormal muscle responses were recorded at the end of the operation, there was a significant difference in this ratio before and after MVD (paired t-test, p < 0.05). There was no significant difference in the ratio before MVD between patients whose abnormal muscle responses were recorded at the end of the operation and patients whose abnormal muscle responses were not (p > 0.05). There was no significant difference of the ratio either before or after MVD between patients who exhibited hemifacial spasm after MVD and patients who did not (p > 0.05).

Postoperative Assessment

Hemifacial Spasm. In eight of 20 patients the hemifacial spasm disappeared completely immediately after MVD. In the other 12 patients residual spasms, which were slight and mild compared to those experienced before MVD, were observed. The mean period from MVD to the final disappearance of hemifacial spasm was 5.1 ± 1.7 months.
The F Waves. In those patients in whom hemifacial spasm was seen postoperatively, the F/M amplitude ratio and the duration of F waves increased significantly on the spasm side (p < 0.05) compared with those on the normal side. There was no significant difference in the frequency of the F wave between the spasm side and the normal side (p > 0.05) (Fig. 6 upper).

Examinations of the patients were conducted within approximately 1 month after the last hemifacial spasm had disappeared completely; after that time no hemifacial spasm occurred. During the 1st month postspasm, the F/M ratio increased significantly (p < 0.05) on the spasm side and there was no significant difference in F-wave duration or F-wave frequency (Fig. 6 center).

One month after the hemifacial spasm had disappeared completely, there were no significant differences in F/M ratio or F-wave duration and frequency between the spasm side and the normal side (Fig. 6 lower).

Blink Reflexes. There was no significant difference (p > 0.05) between the spasm side and the normal side after MVD in the ratio (R2c/R2) or in the recovery rate of the R2 area during an interstimulus interval of 200 msec (Fig. 6).

Abnormal Muscle Response (Lateral Spread). The abnormal muscle response/M-wave amplitude ratio decreased significantly compared with the ratio before MVD in all 12 patients who had spasms after MVD (p < 0.05). Immediately after hemifacial spasm had completely disappeared, abnormal muscle responses were still recorded in seven of 15 patients. One month after the hemifacial spasm had disappeared completely, the abnormal muscle response also disappeared completely in all 20 cases (Fig. 7).

Discussion

The features of enhanced F waves on the spasm side in patients with hemifacial spasm could be described as late responses of variable waveforms demonstrated by an increased F/M amplitude ratio and F-wave duration and
frequency of appearance. It is believed that an increase in the excitability of the facial motor nucleus leads to enhancement of facial F waves. The increase in the F/M ratio and F-wave duration and frequency is, thereby, related to an increase in the excitability of the facial motor nucleus, and those factors on the spasm side directly support a firm relationship between the excitability of the facial motor nucleus and the pathophysiology of hemifacial spasm. The increase in the F/M amplitude ratio might be caused by ephaptic transmission; however, considering that the transmission time of the ephapses is below 100 to 200 μsec, ephaptic transmission alone may not be the cause of the increase in F-wave duration (from several milliseconds to > 10 msec). In patients whose hemifacial spasm did not completely disappear after MVD, there were significant differences in the F/M ratio and the F-wave duration between the spasm side and the normal side; however, there was no significant difference in F-wave frequency and the enhancement of F waves tended to decrease compared with that observed before MVD. The continuously increasing duration of F wave after MVD also suggests hyperexcitability of the facial motor nucleus in patients with hemifacial spasm rather than ephaptic transmission. Within 1 month after the hemifacial spasm had disappeared completely, there was a trend toward enhanced F waves on the spasm side. Enhancement of the F waves continued for approximately 1 month after the disappearance of hemifacial spasm; after that point it disappeared completely. The repetitive stimulation of the facial nerve in our stimulation studies may result in activation of the motor neuron pool in the facial motor nucleus and in enhancement of the F waves and the abnormal muscle responses. Their enhancement, which was measured after the disappearance of hemifacial spasm, may indicate some subclinical spasm but this is not seen on the normal side. This suggests continuous hyperexcitability of the facial motor nucleus lasting approximate-ly 1 month after disappearance of the hemifacial spasm. On the other hand, hemifacial spasms continued for 5.1 ± 1.7 months after MVD. That is to say, the facial motor nucleus hyperexcitability continued for several months after MVD.

The excitability curve of the R2 of blink reflexes in patients with hemifacial spasm discloses a suppression of the inhibitory effect of the conditioning stimulus on the R2 elicited by the test stimulus. In normal subjects the R2 of the test response was absent when the interstimulus interval was 80 to 200 msec. In this study we recorded the blink reflexes and measured the recovery rate of the R2 only on the stimulated side before and after MVD, using an interstimulus interval of only 200 msec, a period during which the test response and conditioning response did not overlap. The reappearance of R2 responses on the stimulated side was common and easy to record; they can be measured on the spasm side before MVD. On the normal side of patients with hemifacial spasm, the R2 response was barely elicited by the test stimulus, similar to normal subjects, which differs from the report of Valls-Sole and Tolosa, in which R2 responses were recordable during test stimulation on the normal side. There was a significant difference in the R2 ratio (R2c/R2) between the spasm side and the normal side. This parameter seems to be one of the indices of the excitability of the facial motor nucleus. After MVD, there was no significant difference in the recovery rate of the R2 and the R2/R2c ratio between the spasm side and the normal side. Measuring the R2 area proved to be unstable and the level of suppression by a conditioning stimulus varied in degree between individuals or trials. It is believed that measuring the F wave provides a better estimate of the excitability than measuring the R2 area.

It is said that the abnormal muscle response may be an exaggerated F wave and may express the hyperexcitability of the facial motor nucleus. There was a linear correlation between the mean value of the F/M amplitude ratios and that of the abnormal muscle responses/M-wave amplitude ratios elicited by marginal mandibular branch stimulation. Using the same surface electrodes on the mentalis muscle, the abnormal muscle response/M-wave ratio seems to express the excitability of the facial motor nucleus quantitatively as well as F waves. This study the abnormal muscle response was always seen until the hemifacial spasm disappeared completely, even if the abnormal muscle response/M-wave ratio calculated after MVD was lower than that calculated before MVD. Within 1 month from the time when the hemifacial spasm disappeared abnormal muscle responses were recorded in approximately one-half of the cases in the present study; these recordings indicated that the hyperexcitability of the facial motor nucleus remained, as demonstrated by the enhancement of the F wave. Changes in the abnormal muscle response and the F waves occur at the same time; this supports the hypothesis that the abnormal muscle response is an exaggerated F wave and that after MVD the hyperexcitability of the facial motor nucleus remains for up to 2 years.

When the residual spasm did not disappear for 1 week to 2 years postoperatively, a slight trace of the abnormal muscle response and a slight enhancement of the F wave...
was still noted. In patients whose facial spasm disappeared completely immediately after MVD, an abnormal muscle response and enhancement of the F waves were often still observed. The abnormal muscle response was seen only in the mentalis muscle following zygomatic facial nerve stimulation and was of a much lower amplitude than that observed prior to surgery. Subsequently, the abnormal muscle response and hemifacial spasm disappeared and the enhanced F waves returned to their normal level. There were no significant differences in these parameters between the spasmside and the normal side.

Even when a reduced abnormal muscle response was recorded in some cases at the end of MVD, the hemifacial spasm was not seen after surgery in such cases.18 In this study a reduced abnormal muscle response was also recorded at the end of the operation in seven of 16 cases, although there were no longer spasms or transient mild spasms. The abnormal muscle response was still recorded in seven of 15 cases within 1 month following the disappearance of the spasm after MVD. In all patients who had transient mild spasms for several months after MVD, the abnormal muscle response did not disappear. Even in cases in which vascular compression was relieved during MVD or in which hemifacial spasm disappeared after MVD, abnormal muscle responses were still recorded because hyperexcitability of the facial motor nucleus appeared to remain as F waves were enhanced.

There are reports of persistent slight facial spasm for a period following MVD.25,26 The period between MVD and complete disappearance of hemifacial spasm was not fixed; it was not dependent on the length of the preoperative period of hemifacial spasm or the presence of abnormal muscle responses at the end of operation. Even if the facial nerve were decompressed and removed from the artery, it would seem that the decompressed facial nerve was still to some extent affected by pulsation of the artery in the posterior fossa after MVD. The effect of arterial pulsation on the facial nerve after MVD would seem to be related to the period of transient mild spasm. These suggest that additional surgery for residual spasm should not be performed for at least 2 years after MVD, because this period is necessary for the disappearance of the hyperexcitability of the facial motor nucleus.

It has been hypothesized that enhanced F waves and abnormal muscle responses have the same origin.22 In the current study, the enhanced F waves and the abnormal muscle responses tended to disappear at the same time after MVD and this supports that hypothesis. The abnormal muscle responses, the enhanced F waves, and the hemifacial spasms may be seen for a while after MVD because of the hyperexcitability of the facial motor nucleus, but they finally disappear almost simultaneously at varying periods after MVD when the hyperexcitability of the facial motor nucleus disappears.

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