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Original Article

Monitoring of abnormal muscle response and facial motor evoked potential during microvascular decompression for hemifacial spasm

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Abstract

Background: To determine whether the monitoring of abnormal muscle response (AMR) and facial motor evoked potential (FMEP) during microvascular decompression (MVD) for hemifacial spasm (HFS) might be useful for predicting the postoperative clinical course and final outcomes.

Methods: We analyzed 45 HFS patients who underwent both AMR and FMEP monitoring during MVD. Patients were divided into two groups on the basis of post-MVD disappearance (group AMR-A) or persistence (group AMR-B) of AMR. With regard to FMEPs, patients were classified into one of the two groups according to the ratio of the final to baseline FMEP amplitudes recorded for the orbicularis oculi muscle: one group with a ratio of <50% (group FMEP-A), and the other with a ratio of ≥50% (group FMEP-B).

Results: Twenty-one of the 26 (81%) patients in group AMR-A were assigned to group FMEP-A, whereas 9 of the 17 (53%) patients in group AMR-B were assigned to FMEP-B ($P < 0.05$). In 38 of the 40 (95%) patients in whom the AMRs disappeared or persisted at amplitudes <50% that at the baseline, HFS had subsided at the final follow-up. Forty of the 42 (95%) patients whose FMEP amplitude ratios indicated reduction in the amplitudes from the baseline, had complete relief of the symptoms. Nineteen of the 20 (95%) patients whose AMRs disappeared after MVD experienced immediate relief of their symptoms after the operation. With regard to 14 of the 20 (70%) patients whose AMRs persisted at the final recordings, the symptoms of HFS improved over time and eventually subsided ($P < 0.001$).

Conclusions: Intraoperative monitoring of both AMR and FMEP during MVD may be useful in predicting the postoperative outcomes in HFS patients. The AMR-related findings may help to predict whether HFS disappears immediately after surgery or some time later.

Key Words: Abnormal muscle response, facial-motor evoked potential, hemifacial spasm, microvascular decompression

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INTRODUCTION

Hemifacial spasm (HFS), which is caused by the contact between a blood vessel and the facial nerve at the root exit zone, is effectively treated by microvascular decompression (MVD). HFS patients show abnormal muscle responses (AMRs) in the upper facial muscles on stimulation of the lower facial nerve branch or in the lower facial muscles on stimulation of the upper facial nerve branch.[2,18,20] Ideally, the goal of intraoperative monitoring is to show the disappearance of AMR when the facial nerve is freed of the pressure by the offending vessels.[4,14,16,19,21,25] We have previously emphasized that AMR monitoring is valuable for detecting the offending vessels and ensuring excellent postoperative results.[4,6,9,29] However, the clinical usefulness of AMR monitoring in predicting the postoperative outcomes has been considered debatable.[11,15]

In a recent study, we used facial motor evoked potential (FMEP) elicited by transcranial electrical stimulation to evaluate and monitor the activity of the facial nerve during skull base surgery.[7,8] In HFS patients, the amplitude of the FMEP obtained for the orbicularis oculi muscle has been reported to decrease after the completion of MVD.[5] The results possibly reflect the normalization of facial nerve excitability. We hypothesized that the monitoring of FMEP would be as useful as that of AMR in predicting the postoperative outcome in HFS patients undergoing MVD.

In this study, we investigated the correlation between the AMR and FMEP measurements obtained during MVD and sought to clarify whether the monitoring of both AMR and FMEP is useful for predicting the postoperative clinical course and final outcomes.

MATERIALS AND METHODS

Patients

The study involved 45 patients (11 men and 34 women) who underwent AMR and FMEP monitoring during MVD for HFS at the University of Niigata between July 2005 and December 2010. The mean age of the patients at surgery was 54.3 years (range, 25–70 years), and the median duration of the symptoms was 65.1 months (range, 5–180 months). In all the selected cases, the spasm originated in the orbicularis oculi muscle. At surgery, only the orbicularis oculi muscle was found to be involved in three cases, whereas the additional involvement of the orbicularis oris muscle was noted in the others.

Surgery

After the administration of a short-acting agent for neuromuscular blockade, neuroanesthesia was maintained by intravenous infusion of propofol and fentanyl. Until the completion of MVD, muscle relaxants were not used. Patients were placed in the lateral oblique position, with the head fixed in a neutral position and rotated slightly toward the surgeon. The glossopharyngeal and vagal nerves were identified after dissecting the arachnoid around the cerebellomedulary cistern. The root exit zone of facial nerve was ascertained close to the brainstem via the infrafloccular route. The offending vessel was shifted off the facial nerve by adhering it to the dura covering the pyramidal bone or by inserting a small piece of shredded Teflon felt between the vessels and the brainstem or the flocculus. None of the patients included in this case series underwent interpositioning of the offending vessel and the facial nerve.

Intraoperative monitoring

A Viking monitoring system (Nicolet Biomedical, Inc., Madison, WI, USA) was used for intraoperative monitoring. Paired stimulating stainless-steel needle electrodes were subdermally inserted both into the lower edge of the zygomatic bone as the temporal branch being stimulated and into the lower edge of the mandibular bone (about 3 cm apart from the midline) as the marginal mandibular branch being stimulated. AMRs were recorded from the mentalis muscle after electrical stimulation of the temporal branch of the facial nerve and from the orbicularis oculi muscle after stimulation of the marginal mandibular branch. Paired stainless-steel needle electrodes were subdermally inserted into the relevant muscles. AMRs from the orbicularis oculi and mentalis muscles were recorded using amplifiers with a frequency band of 5 Hz to 3 kHz. The muscles were then subjected to supramaximal stimulation.

FMEPs were recorded from the orbicularis oculi, mentalis, and orbicularis oris muscles. MEPs recorded from the ipsilateral thenar muscle were used as control responses. The bandpass filter was set at a frequency of 200–3000 Hz. The FMEP amplitude was defined as the range between the maximum positive and negative peaks of the polyphasic waveform. Corkscrew electrodes were placed at positions C3 or C4 and Cz to stimulate FMEPs. The cathode was always positioned at Cz, while the anode was positioned at the contralateral side. Constant voltage stimuli consisting of five rectangular pulses at intervals of 1 ms were generated using a D185 stimulator (Digitimer Ltd., UK). The stimulation intensity was increased gradually until the FMEP amplitudes obtained from the orbicularis oculi, mentalis, and orbicularis oris muscles reached a plateau before dural opening because the stimulus was adjusted to the supramaximal intensity, which ranged from 152 to 600 V (mean, 321 V).

Both AMR and FMEP recordings were obtained at each stage of MVD, i.e. upon opening of the dura, retraction of the cerebellum, transposition of the offending vessels, termination of the microsurgical procedure, and dural closure. If the AMR disappeared completely or the amplitude decreased to $< 50\%$ compared to the baseline level, the response was judged to be changed by decompression of the facial nerve. In order to determine that disappearance of AMR was not due to technical errors, the direct response amplitude was confirmed to be not changed. Occasionally, the AMR disappeared when the cerebrospinal fluid was drained or when retractors were placed in the cerebellum. AMR monitoring was continued at the same intensity of stimulation until the compression of the facial nerve by the offending arteries was completely eliminated. If the AMR did not change from the response at the baseline (before dural opening) despite decompression, we explored to region for any other possible underlying causes, such as compression by another vessel, in order to achieve the optimal decompression of the facial nerve. When no other offending vessels were identified by the additional investigation, further manipulation was avoided even if the AMRs persisted.

Evaluation and statistical analysis

According to surgical outcomes, all patients were evaluated whether their symptoms disappeared completely or persisted at 1 year after surgery.

The patients were divided into two groups on the basis of whether the AMRs disappeared (group AMR-A, Figure 1a and b) or persisted (group AMR-B, Figure 2a and b) after MVD. The ratios (shown as percentages) of the final (at dural closure) to the baseline FMEP amplitudes were used for the analysis. We have previously demonstrated that the final-to-baseline FMEP amplitude ratio obtained from the orbicularis oculi muscle was significantly lower than that obtained from the two other muscles.[5] Therefore, only the FMEP ratios obtained for the orbicularis oculi muscle were evaluated. Further, patients were classified into one of the two groups according to the FMEP ratio obtained for the orbicularis oculi muscle: one group with a ratio of <50% (group FMEP-A, Figure 1c), and the other with a ratio of ≥50% (group FMEP-B, Figure 2c).

Statistical analysis was performed using commercial software (SPSS, SPSS Inc, Chicago, IL). The χ^2- test was used to assess the statistical significance of the independent variables between the AMR and FMEP findings. An independent *t*-test was also used to compare the postoperative clinical courses of the two sets of groups (AMR-A and AMR-B, and FMEP-A and FMEP-B). A value of $P < 0.05$ was considered significant.

RESULTS

Surgical results

In the case of 42 of 45 patients (93%), HFS had completely disappeared 1 year after surgery. For 21 of the 42 patients (50%), the spasm completely disappeared immediately after surgery, while for the remaining 21, the symptoms reduced gradually and resolved completely within 1–25 weeks (mean, 8.9 weeks) of MVD. With regard to the remaining 3 of 45 patients, one did not show any improvement after surgery and the HFS persisted until a year after MVD, at an intensity 50% of that before surgery. The other two of these three patients developed recurrence of their symptoms 3 months after surgery, and postoperative magnetic resonance imaging scans showed that the transposed vessels had returned to the preoperative positions and compressed the facial nerve again. One of the two patients underwent reoperation, after which the symptoms subsided after the second surgery. The other patient is currently being followed up as an outpatient.

No major postoperative complications occurred. Transient facial palsy occurred in two patients. Hearing disturbance and transient swallowing disturbance each occurred in one patient each.

Abnormal muscle response findings

In the case of two of the three patients in whom the spasm was localized to the orbicularis oculi and did not spread to the lower part of the face, the AMRs were recorded from neither the orbicularis oculi nor the mentalis muscle. For 8 of the remaining 43 patients, the AMRs were obtained only from the mentalis muscle. In the case of 26 of the 43 patients (group AMR-A, 60.5%) whose intraoperative recordings of AMRs were available for evaluation, the abnormal responses had completely disappeared by the end of the microsurgical procedures. The other 17 patients (group AMR-B, 39.5%) had persistent AMRs despite intraoperative confirmation of the absence of any other vessel compressing the facial nerve. In the case of six and one of the 17 patients, the AMRs recorded from the orbicularis oculi and mentalis muscles, respectively, disappeared after MVD, but those recorded from the corresponding mentalis and orbicularis oculi muscles persisted with an amplitude reduction of ≤50%. In another 7 of the 17 patients, the amplitude in AMRs obtained from both orbicularis oculi and mentalis muscles decreased to <50% that at the baseline after MVD. The remaining three patients did not show any change in the AMR waveforms at the final recording.

Facial motor evoked potential findings

For all the patients, the available FMEPs were obtained from the orbicularis oculi muscles. In the case of 30 of 45 patients, the ratio of the final-to-baseline FMEP amplitude reduced to <50% (group FMEP-A, 66.7%). The remaining 15 patients were assigned to group FMEP-B (33.3%). In 3 of the 15 patients, the waveform of the final FMEPs remained unchanged after MVD, and the amplitude ratios were more than 100%.

Abnormal muscle response and facial motor evoked potential findings

The disappearance of AMRs or a decrease in their amplitude was almost simultaneously with the reduction in the amplitude of FMEP. In the case of two patients in whom AMRs could not be recorded, the decrease in the amplitude of the FMEP obtained from the orbicularis oculi muscle enabled the surgeons to confirm

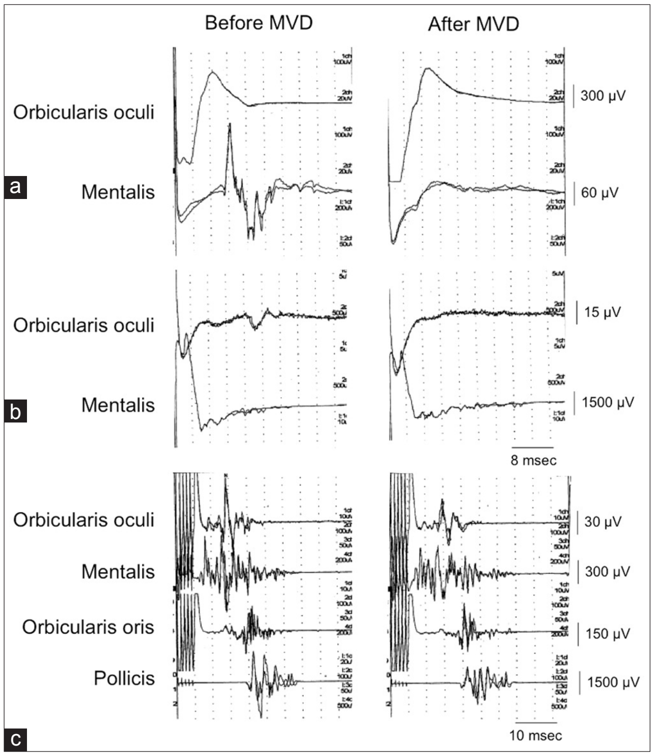

Figure 1: Intraoperative abnormal muscle response (AMR) from the mentalis (a) and from the orbicularis oculi muscle (b) and facial motor evoked potential (FMEP) recordings (c) in a patient with hemifacial spasm (HFS) assigned to group AMR-A and FMEP-A. Both responses recorded from the two muscles disappeared completely after microvascular decompression (MVD, group AMR-A). FMEP amplitude obtained from the orbicularis oculi muscle decreased to 36% of that before MVD (group FMEP-A)

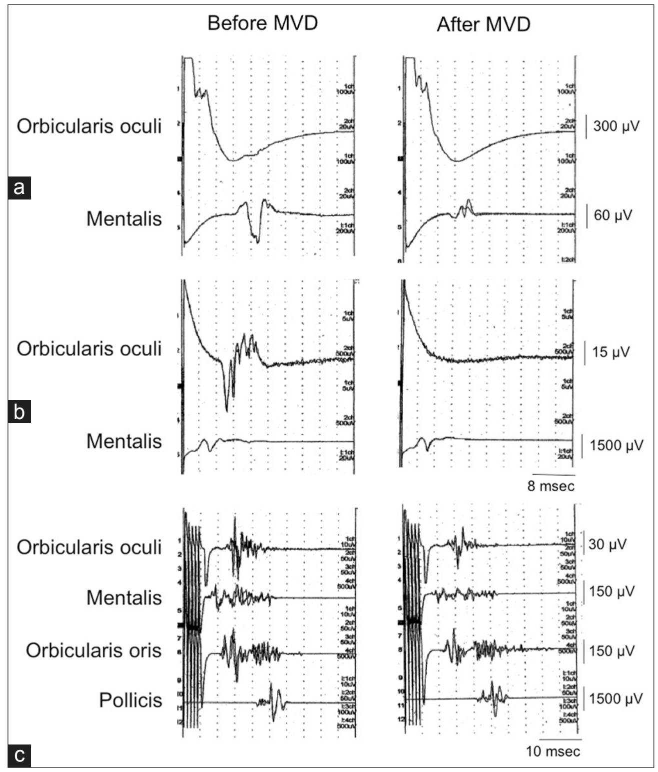

Figure 2: Intraoperative AMRs recorded from the mentalis (a) and from the orbicularis oculi muscle (b) and FMEP recordings (c) in another patient with HFS assigned to groups AMR-B and FMEP-B. AMRs recorded from the orbicularis oculi muscle completely disappeared after MVD, whereas those from the mentalis muscle remained despite a decrease in AMR amplitude to <50% that at the baseline (group AMR-B). FMEP amplitude obtained from the orbicularis oculi muscle decreased to 69% of that before MVD (group FMEP-B)

the completion of MVD. Further, for three patients whose AMR waveform remained the same as that at the baseline, the FMEPs also remained unchanged, and the amplitude ratios were more than 100%. In the case of 21 of 26 patients (80.8%) whose AMRs disappeared after MVD (group AMR-A), the final FMEP amplitude ratios were <50% (group FMEP-A). With respect to 9 of 17 patients (52.9%) with persistent AMRs after MVD (group AMR-B), the final FMEP ratios were >50% (group FMEP-B, $\chi^2 = 5.3$, $P < 0.05$, Figure 3).

Relationship between intraoperative abnormal muscle response and facial motor evoked potential findings and outcomes

One year after surgery, 38 of the 40 patients (95.0%) whose AMRs disappeared or decreased in amplitude to <50% that at the baseline had complete relief of HFS. Similarly, 40 of the 42 patients (95.2%) whose FMEP amplitude ratios indicated reduction in the amplitude from the baseline showed complete disappearance of the symptoms. The remaining two patients had recurrences 3 months after surgery due to recompression of the facial nerve by the offending vessels. Three patients in the study showed neither changes of AMR waveforms nor decreases in the FMEP amplitude, despite the confirmation of complete facial nerve decompression. One of the three patients had HFS at an intensity similar to that at the baseline immediately after surgery and experienced remained symptoms at the final follow-up. In the remaining two patients, surgeons had stopped further manipulations after they confirmed the absence of other vessels compressing the facial nerve, even at distal sites: the manipulation was stopped even though both the AMR and FMEP waveforms remained unchanged after the operation. However, after the surgery, their symptoms gradually decreased and disappeared at 7 and 16 postoperative weeks.

Relationship between intraoperative abnormal muscle response and facial motor evoked potential findings and postoperative course

Among patients (n = 40) whose AMRs were available and HFSs had completely disappeared at the last follow-up, 19 of 20 patients (95.0%) in whom AMRs disappeared after MVD experienced immediate disappearance of their symptoms after surgery. Among 14 of 20 patients (70.0%) in whom AMRs persisted at the final recordings, the HFSs reduced in intensity over time and eventually subsided (χ^2 = 18.0, P < 0.001, Figure 4). On the other hand, in the case of patients (n = 42) whose FMEPs were recorded and HFSs disappeared completely, the FMEP amplitude ratios were not statistically correlated with the postoperative course (χ^2 = 2.1, P = 0.19, Figure 5).

DISCUSSION

In this study, the recordings of both AMRs and FMEPs obtained from the orbicularis oculi muscle were found to be useful in predicting the postoperative outcomes in HFS patients. The disappearance of AMRs or a reduction of their amplitude to 50% or less at the final recording was associated with complete relief of symptoms 1 year after surgery in 95% of the patients. A reduction in the FMEP amplitude at the final recordings compared to that at the baseline was also associated with good outcomes in 95% of the patients. Intraoperative AMR findings were related to the postoperative course, i.e. whether HFS disappeared immediately after surgery or subsided gradually over time. The disappearance of AMRs after decompression was associated with the patient being symptom-free immediately after surgery.

The clinical usefulness of intraoperative AMR monitoring in predicting the postoperative outcomes has been a topic of debate. Many studies have investigated the association between the disappearance or persistence of AMRs after decompression and the outcome of MVD.[10,11,15,16] A recent meta-analysis revealed that the postoperative failure rate was 39% and 9.5% for patients without and with disappearance of AMRs after decompression, respectively; thus, the chance of a cure if the AMR disappeared after MVD was 4.2 times greater than that if the AMR persisted.[25] On the other hand, some studies have investigated whether the amplitude in the persistent AMR decreased from that present before decompression.[6,9,21,26,29] Among patients with persistent AMRs at the end of the operation, those with a reduction in the AMR amplitude frequently experienced complete resolution after the operation.[6,9,21,29] Consistent with this finding, our results showed that 95% of the patients with abolishment of the AMR or AMR reduction to 50% or less had no symptoms at the final follow-up. However, in two cases wherein AMR had disappeared or decreased at the final recordings, the symptoms relief was only transient and HFSs recurred 3 months after the operation. In both these cases, postoperative magnetic resonance imaging revealed that the offending arteries recompressed the facial nerve. Thus, we can infer that intraoperative AMR monitoring may not facilitate the prediction of the recurrence of symptoms. Except for these two patients, all others with AMR cessation or decreased AMRs had excellent outcomes. Thus, AMR monitoring is useful for predicting the postoperative symptom-free status of patients, if AMR amplitude reduction is also considered as a significant indicator of the completion of decompression of the facial nerve.

In the case of two of our patients who did not show any change in the AMRs after the surgery, complete relief of the spasm was attained only in a gradual manner, despite confirmation of the absence of any other vessels compressing the facial nerve. Debate has continued as to whether AMR originates from a central[12,13] or peripheral site.[22–24] In our previous studies,[4,9,28,29] AMR has been shown to originate mainly from the cross-transmission at the compression site. Thus, the disappearance of AMRs probably indicates that the cross-transmission at the compression sites is abolished by shifting the offending

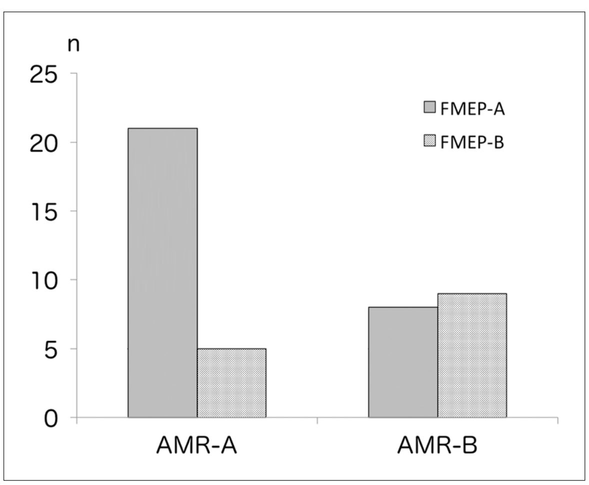

Figure 3: Bar graphs showing the relationship between AMR and FMEP findings. The results revealed that 21 of 26 patients (81%) with disappearance of AMRs after MVD (group AMR-A) had FMEP amplitude ratios of <50% (group FMEP-A) for the orbicularis oculi muscle. In 9 of 17 patients (53%) in group AMR-B, the FMEP amplitude ratios were more than 50% (group FMEP-B, $\chi 2$ = 5.3, *P* < 0.05)

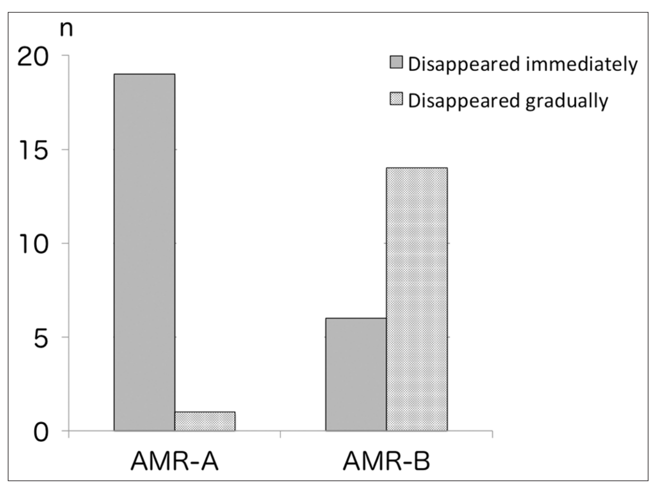

Figure 4: Bar graphs showing the relationship between AMR findings and postoperative course. Nineteen of 20 patients (95%) in group AMR-A had immediate relief of HFS after the operation, whereas 14 of 20 patients (70%) in AMR-B experienced gradual relief of HFSs (χ^2 = 18.0, *P* < 0.001)

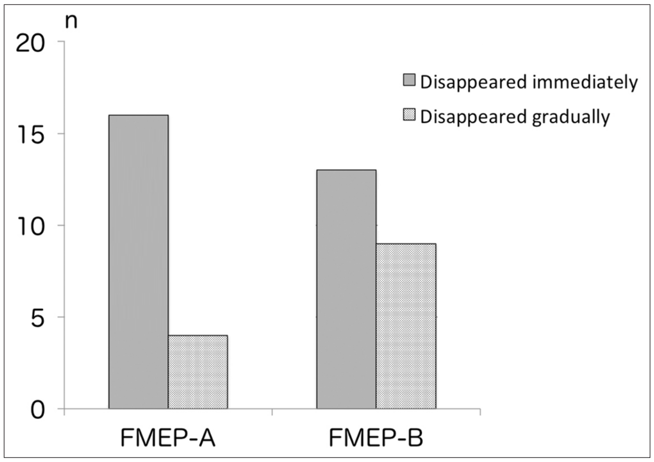

Figure 5: Bar graphs showing the relationship between FMEP findings and postoperative course. In 42 patients whose FMEPs were recorded and had complete disappearance of HFSs, no significant differences were noted between groups FMEP-A and FMEP-B with regard to the postoperative course: i.e. whether their HFSs disappeared immediately after the operation or subsided gradually (χ^2 = 2.1, *P* = 0.19)

vessels away from the facial nerve. Consistently, some patients with persistent AMRs after the surgery possibly have the involvement of the kindling of the facial nucleus in addition to this cross-transmission. Their symptoms of such patients do not disappear immediately after surgery, but decrease in severity along with a gradual decrease in the intensity of the kindling of the facial nucleus. Indeed, in this study, the patients with persistent AMRs more frequently experienced gradual improvement in their HFS after surgery than those with disappearance of AMRs. In the case of two of our patients, AMRs could be mainly related to the hyperexcitability of the facial motor neurons, which is probably rare in HFS patients. Although no data regarding postoperative AMRs were available, their symptoms had become weaker and had probably decreased in amplitude over time. When the kindling of the facial neuron was normalized, HFS subsided completely along with the disappearance of AMR.

In this study, the AMR findings were significantly correlated with the amplitude of FMEP recorded for the orbicularis oculi muscle. Patients with disappearance of AMRs had a higher frequency of FMEP amplitude ratios of <50% compared to others. Similarly, those with persistence of AMRs had FMEP amplitude ratios of more than 50% more frequently than those without. In three of our patients, the waveforms of both AMR and FMEP remained unchanged at the final recordings. A previous study has also shown that the disappearance or decrease in the amplitude of AMR occurred simultaneously with the decrease in the FMEP amplitude.[5,27] Although AMR is assumed to originate mainly because of cross-transmission, it is unclear whether the reduction in FMEP after MVD is caused by the normalization of the hyperexcitability of the facial motor neuron or the disappearance of the cross-transmission at the compression sites. Because anatomical structures related to FMEP include both the facial motor nucleus and the site of compression of the facial nerve,[1,3,17] FMEP could be equally generated by the central sites or the peripheral sites. Our results showed that the reduction in the FMEP amplitude recorded from the orbicularis oculi muscle after MVD was significantly correlated with the disappearance or decrease in AMRs and favorable outcomes in HFS patients. In addition, two patients for whom no AMRs were recorded showed a decrease in the FMEP amplitude, thereby allowing the surgeons to confirm complete decompression. The postoperative decrease in the FMEP amplitude obtained for the orbicularis oculi muscle is believed to reflect the normalization of the hyperexcitability of the facial nerve at both the compression site and the facial nucleus. Although FMEP may not predict whether HFS disappeared immediately or subsided gradually, its monitoring may be as useful as AMR monitoring in predicting the postoperative outcomes.

CONCLUSION

Disappearance of AMRs or a 50% or more reduction in their amplitude and reduction in the FMEP amplitude of the orbicularis oculi muscle after MVD were predictive of postoperative relief of HFS. HFS patients with cessation of AMRs were more frequently symptom-free immediately after surgery than those with persistence of AMRs. The recording of both AMRs and FMEPs for the orbicularis oculi muscle is useful monitoring for predicting the postoperative outcomes in HFS patients.

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