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Waveform reliability with different recording electrode placement in facial electroneuronography

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Abstract

Electroneuronography (ENoG) has become a useful test for estimating the degree of facial nerve degeneration and predicting the prognosis in patients with facial nerve palsy. Test results may be influenced by several factors, including the electrode positions, skin resistance, stimulus magnitude, and possible artifacts. Regarding recording electrode positions, different groups have used two different locations, the nasolabial fold and nasal ala. The authors compared the waveforms recorded from these two locations in ENoG recordings to obtain the optimal waveform. Twenty healthy volunteers and 25 patients with unilateral facial nerve palsy were included in this study. Recordings were carried out with the recording electrode placed on the nasolabial fold, followed by placement on the nasal ala after 10 minutes. The following parameters were assessed: (1) the supramaximal threshold, (2) amplitude and shape of the waveform, (3) interside difference, and (4) test-retest variability. There was no significant difference in the amplitude of the waveform, interside difference, and test-retest variability between the two groups. However, when the electrode was placed on the nasal ala, the threshold was significantly lower, an ideal biphasic configuration was present in almost all cases (97.5 per cent) of normal volunteers and it was easier to identify the waveform. Placement of the recording electrode on the nasal ala would be the preferred method.

Key words: Facial paralysis; Electrodiagnosis; Electrodes

Introduction

Esslen and Fisch wrote their first description of electroneuronography (ENoG) in 1977, since then, ENoG has become the mainstay in the workup of patients with facial nerve palsy in estimating the degree of degeneration and predicting the prognosis and time of surgical intervention.[1–3] ENoG, also referred to as evoked electromyography, uses computer analysis to objectively measure the difference between compound muscle action potentials generated by the facial musculature on either side of the face in response to a supramaximal electrical stimulus of the facial nerve. The degree of degeneration is quantified by comparing the amplitude of response with the unaffected site, and makes it possible to obtain more objective and quantitative results of the functional facial nerve status.[3,4]

In order to improve the sensitivity and specificity of ENoG recording, the intertest variability needs to be reduced. Several factors should be considered: (1) easy determination of supramaximal threshold, (2) constant amplitude of the recording waveform, (3) obtaining an ideal biphasic waveform, and (4) decreasing interside difference and test-retest variability. It is thought that these waveforms change with the location and pressure of the electrode, skin resistance, and the stimulating electric current.[5]

Regarding the recording electrode, different authors have placed the electrode in different locations. In the early reports of Esslen and Fisch *et al.,* the recording electrodes were placed on the nasolabial fold, which has been widely used ever since.[4] However, May and Hughes *et al.* preferred the nasal ala because of better recognizable waveforms and less contraction of masticator muscles.[2,6]

The authors compared the waveforms from the nasal ala and nasolabial fold in ENoG recordings in terms of several parameters: (1) determining the supramaximal threshold, (2) amplitude and shape of the waveform, (3) interside difference, and (4) test-retest variability.

This study was designed to identify the optimal recording electrode location for facial ENoG in order to obtain the optimal waveform and minimize the artifacts.

Materials and methods

Twenty healthy volunteers (15 males, five females; mean age 30.4 years, range 27–39 years) without any

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viral illness or facial nerve palsy history were included as controls. The diseased group consisted of 25 patients with unilateral facial nerve palsy (14 males, 11 females) with a House-Brackman grade over III and an onset of less than two weeks.

ENoG recordings were obtained on a Nicolet Viking IV (Madison, Wisconsin, USA) using bipolar cutaneous electrodes. With the subject positioned supine and without any pretreatment, the centre of the stimulating electrode was placed between the posterior margin of the mandible and the tip of the mastoid on the test side after cleansing with alcohol. The ground electrode was placed on the right arm. Recording began with the recording electrode placed on the nasolabial fold, followed by placement on the nasal ala after 10 minutes. When the recording electrode was placed on the nasolabial fold, the reference electrode was placed on the lateral part of the nasal ala, the superior portion of the nasolabial fold, and the active electrode was placed about 2 cm inferior to it. When placing the recording electrode on the nasal ala, the active electrode was placed on the test side with the reference electrode placed on the opposite side (Figure 1). To obtain the best waveform, an optimized lead placement (OLP) technique[9,10] was applied. With this technique, the recording electrode was moved around to find out the best waveforms with least artifacts. The following six parameters were assessed: (1) the magnitude of supramaximal stimulating threshold, (2) waveform amplitude, (3) waveform sharpness, (4) waveform shape, (5) interside difference, and (6) test-retest variability.

To obtain a supramaximal stimulating threshold, the stimulus (applied at a rate of one per second and duration of 0.2 msec) was started at 10 mA and increased to 80 mA at a step size of 10 mA. The resistance between the skin and electrode was less than 10 kΩ. The stimulus threshold was determined when the waveform amplitude did not increase as the stimulus intensity increased; the test was performed at a stimulus 10 per cent higher than the threshold stimulus, this was called the supramaximal threshold. When the threshold was not obtained at a current less than 80 mA, the test was performed at a stimulus intensity of 80 mA. If the subject felt pain during stimulation at an intensity lower than 80 mA, then the recording was performed using that current.

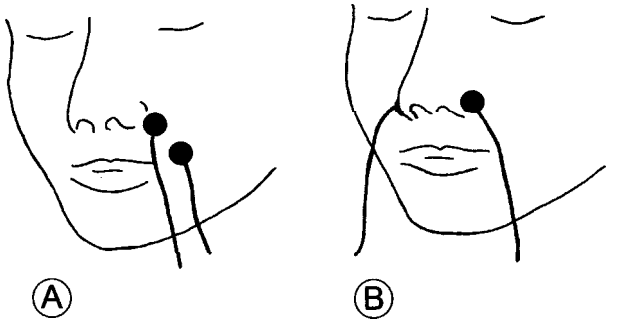

FIG. 1

(a) Placement of the recording electrode on the nasolabial fold. The reference electrode was placed on the lateral part of the nasal ala, the superior portion of the nasolabial fold, and the active electrode was placed about 2 cm inferior to it. (b) Placement of the recording electrode on the nasal ala. The active electrode was placed on the test side with the reference electrode placed in the opposite side.

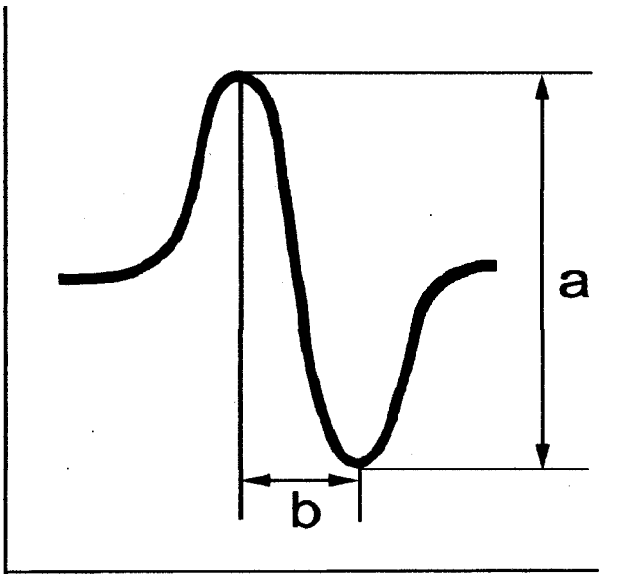

FIG. 2

Measuring the amplitude and sharpness. The amplitude was obtained by measuring the peak-to-peak voltage between the early positive and late negative deflection peak (a). Sharpness was defined as the ratio of the amplitude to the time difference between the positive and negative peaks (a/b).

The amplitude was obtained by measuring the peak-to-peak voltage between the early positive and late negative deflection peak of the muscle compound action potential (Figure 2).

Two features of the waveform were defined: (1) the waveform sharpness was defined as the ratio of the amplitude to the time difference between the positive and negative peaks (Figure 2), and (2) the morphology of the wave was classified into three groups, biphasic synchronous, biphasic asynchronous, and multiphasic (Figure 3). In a biphasic synchronous waveform (Figure 3(a)) a symmetric negative deflection followed a positive deflection, whereas in a biphasic asynchronous waveform (Figure 3(b)) the following negative deflection was asymmetric. In a multiphasic waveform (Figure 3(c)) there were more than three deflections.

Interside difference ((1 – (smaller waveform/larger waveform))×100(%)) and test-retest variability

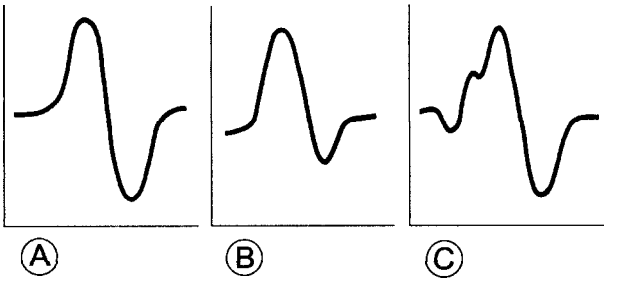

FIG. 3

The morphology of the wave was classified into three groups, biphasic synchronous (A), biphasic asynchronous (B), and multiphasic (C).

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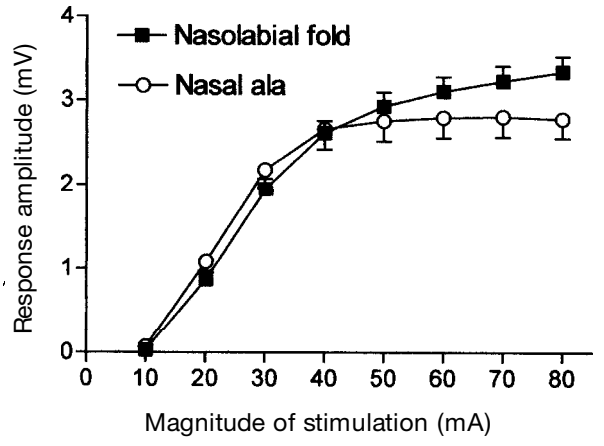

FIG. 4

Response amplitude as a function of stimulus intensity in normal group. When recorded in the nasal ala, the amplitude increased until the stimulus intensity went up to 40 mA and then plateauxed. But, when recorded in the nasolabial fold, the amplitudes did not plateau and increased as the stimulus intensity increased above 40 mA. Error bar is standard deviation.

have been assessed bilaterally on normal volunteers at the nasolabial fold and nasal ala, respectively, with the stimulation of supramaximal threshold. To obtain the test-retest variability in normal volunteers, the tests were repeated at a mean of 4.8 days after the first recording.

Statistical analysis was performed using the parametric Student *t*-test to compare the difference between the nasolabial fold group and nasal ala group. The differences were considered statistically significant for $p<0.05$.

Results

A total of 40 waveforms from both sides of normal volunteers and 25 waveforms in unilateral facial nerve palsies were obtained in each group.

It was much easier to determine the supramaximal threshold from recordings on nasal ala than those on the nasolabial fold. In normal volunteers, the amplitudes recorded on the nasal alae increased for a stimulus intensity of up to 40 mA by a step of 10 mA, and then plateauxed for higher stimulus intensities. However, when recorded on the nasolabial fold, the amplitudes did not plateau and increased even at stimulus intensities of above 40 mA (Figure 4). In normal volunteers, the mean supramaximal threshold was 44.9 mA (standard deviation = 15.9 mA) on the nasal ala. The mean and standard deviation of the supramaximal threshold recorded on the nasolabial fold were 56.6 mA and 16.2 mA, respectively. It was significantly higher in the nasolabial fold in the normal group ($p<0.05$). In patients with unilateral facial nerve palsy, the supramaximal threshold in the nasolabial fold was significantly higher than in the nasal ala ($p<0.05$), too. The authors found that the threshold in the palsy side was higher than the normal side with either recording method (Table I).

The amplitude recorded at the nasolabial fold was higher than that at the nasal ala, but the difference was not statistically significant ($p>0.05$). The waveform sharpness was significantly higher in recordings at the nasal alae than those at the nasolabial folds in both groups. Statistical significance was also noted in the patient group ($p<0.05$) (Table II).

In the normal volunteer group, biphasic waveforms were the most common on the nasal alae (97.5 per cent), and multiphasic on the nasolabial folds (62.5 per cent), which is indicative of artifacts from masticator muscle contraction (Table III). In the patient group, multiphasic waveforms were not observed when the electrode was placed on the nasal alae, but 16 per cent exhibited multiphasic waveforms when the electrode was placed on the nasolabial folds (Table IV).

The average interside difference was 19.3 per cent (range 0.3–33.9 per cent) on the nasolabial folds and 20.9 per cent (range 1.1–39.9 per cent) on the nasal alae. There was no statistically significant difference between these different recording groups (Table V).

The average test-retest variability in normal group was 20.6 per cent on the nasolabial folds and 21.0 per cent on the nasal alae. This difference was also not significant.

TABLE I

SUPRAMAXIMAL THRESHOLD MEASURES IN NORMAL AND FACIAL PALSY PATIENTS

		Facial palsy patients (n = 25)	
	Normal (n = 40)*	Palsy side*	Normal side
Nasolabial fold	56.6 ± 16.2	60.5 ± 12.8	55.0 ± 15.5
Nasal ala	44.9 ± 15.9	55.0 ± 15.5	45.4 ± 14.1

Data shown in mean ± standard deviation
$p<0.05$ Comparison between the two recording methods

TABLE II

MEAN VALUE OF AMPLITUDE AND SHARPNESS (=AMPLITUDE/DURATION) FOR TWO DIFFERENT RECORDING ELECTRODE PLACEMENTS

	Normal (n = 40)		Facial palsy (n = 25)	
	Amplitude*	Sharpness**	Amplitude*	Sharpness**
Nasolabial fold	3.277 ± 1.153	0.292 ± 0.098	1.31 ± 0.88	0.141 ± 0.094
Nasal ala	2.110 ± 1.086	0.653 ± 0.322	0.93 ± 0.63	0.369 ± 0.341

*$p>0.05$, **$p<0.05$ Comparison between the two recording methods

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TABLE III
MORPHOLOGY OF WAVEFORM FOR TWO DIFFERENT RECORDING ELECTRODE PLACEMENTS IN NORMAL VOLUNTEERS (%)

	BS	BA	MP	Total
Nasolabial fold	10 (25.0)	5 (12.5)	25 (62.5)	40 (100)
Nasal ala	25 (62.5)	14 (35.0)	1 (2.5)	40 (100)

BS = biphasic synchronous; BA = biphasic asynchronous; MP = multiphasic

TABLE IV
MORPHOLOGY OF WAVEFORM IN PATIENTS WITH UNILATERAL FACIAL NERVE PALSY (%)

	BS	BD	MP	Total
Nasolabial fold	12 (48.0)	9 (36.0)	4 (16.0)	25 (100)
Nasal ala	17 (64.0)	8 (36.0)	0 (0.0)	25 (100)

BS = biphasic synchronous; BA = biphasic asynchronous; MP = multiphasic

- **Electroneuronography (ENoG) is a useful test for estimating the degree of facial nerve degeneration and predicting the prognosis in patients with facial nerve palsy**
- **Test results may be influenced by electrode positions, skin resistance, stimulus magnitude and possible artifacts**
- **Comparison is made of waveforms derived from electrodes placed separately on the nasolabial fold and the nasal ala**
- **The authors conclude that placement of the recording electrode on the nasal ala gives better results than on the nasolabial fold**

Discussion

To increase the reliability of ENoG testing, many factors involved in recording the evoked response should be constant.[1] Interside difference and test-retest variability needs to be lower and several factors influencing the test results such as the electrode positions, skin resistance, stimulus magnitude, and masseter artifacts should be controlled. Regarding the recording electrode position, facial ENoG with two different recording electrode locations, the nasolabial fold and nasal ala, did not produce any different result in the interpretation of the degree of facial nerve degeneration in terms of the amplitude of response, interside difference and test-retest variability. However, when recorded on the nasal ala, the supramaximal threshold was lower and more easily determined, making it less bothersome for the patients. Moreover, the ideal biphasic waveforms were present in most cases, which is related to fewer artifacts. A significant increase in the waveform sharpness may help examiners pick up the optimal wave more easily.

The supramaximal intensity thoroughly stimulates all surviving nerve fibres. As the stimulating intensity increases, the compound action potential increases and the maximal amplitude is produced. The supramaximal threshold is usually set at approximately 10–20 per cent above the maximal intensity.[1] However, such an extreme stimulating threshold would cause an artifact due to its stimulation of the masseter and pterygoid muscles (innervated by the trigeminal nerve) and cause pain, especially in children.[7] This study found that the amplitudes plateauxed on the nasal alae at a stimulus intensity of 40 mA in normal volunteers. Therefore the threshold was more easily determined: the mean supramaximal threshold was 44.9 mA. Meanwhile, when the electrodes were placed in the nasolabial folds, the threshold was highly affected by artifacts from the masseter muscle. In the stimulus-response curve, the authors found that as the stimulus intensity increased, the amplitude continued to increase. In patients with facial nerve palsy, the supramaximal threshold was higher in the palsy side than that in the normal side. Nonetheless, the threshold recording from the nasolabial fold was higher than the nasal ala in these patients. Sometimes, it was difficult to set the supramaximal threshold, and hence the recording was performed either at 80 mA (the maximal stimulating intensity) or at the intensity where the patient felt pain. It was often difficult to obtain a correct waveform especially in children due to their poor cooperation, making the determination of the supramaximal threshold difficult. Therefore, to obtain an ideal stimulus threshold, the stimulus itself should be less painful to facilitate cooperation, which might be one of the important factors in reducing test errors, since stimulating the trigeminal nerve is less likely. In that sense, the nasal ala is to be preferred to the nasolabial fold in order to lower the supramaximal threshold.

It is widely known that the amplitude is related to the numbers and synchronicity of the nerve fibres responding to the stimulus.[8] The amplitude of the waveform was higher on the nasolabial fold, but the difference was statistically not significant in this study, which indicated that there was no difference in the minimal muscle amount affecting the ENoG recordings between the two groups.

TABLE V
AVERAGE INTERSIDE AND TEST-RETEST DIFFERENCE IN DIFFERENT ELECTRODE PLACEMENTS (%)

	Interside difference*	Test-retest difference*
Nasolabial fold	19.3 ± 11.1	20.6 ± 13.9
Nasal ala	20.9 ± 15.1	21.0 ± 15.9

Data shown in mean ± standard deviation
*$p>0.05$ Comparison between the two recording methods

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The main effects of recording electrode placement on ENoG recordings were the waveform sharpness and incidence of multiphasic waveforms. The ideal ENoG waveform has an initial positive deflection followed by a negative deflection (biphasic synchronous). This biphasic configuration was present in almost all cases (97.5 per cent) from the nasal alae, but multiphasic waveforms were detected in 62.5 per cent of recordings from the nasolabial folds. The multiphasic waveforms may be related to artifacts of masticator muscle contraction, which interfere in the assessment of suprathreshold stimulus level and the recording amplitude.

Muscular components in the nasolabial fold include lip muscles—which contribute to oral competence and the diversity of lip movement—such as orbicularis oris, levator labii superioris, zygomaticus major and minor, ala nasalis, and levator anguli oris muscles. Moreover, trigeminal-nerve-innervated masticator muscles are situated close to the nasolabial fold. Their close relation with the masticator muscle may induce multiphasic waveforms, which might make it difficult to assess the supramaximal threshold and interpret the test results. However, only the smallest portion of the mimic muscles, such as the dilator naris anterior, ala nasalis, and paranasal muscle, lie in the nasal alae and hence make detection of an ideal waveform more likely.[7]

A significant difference was noted in the sharpness, defined as the ratio of the amplitude to the time difference between the negative and positive peaks, according to the placement of electrode in both the normal and patient groups. The waveform duration did not influence the analysis.[9] However, the sharpness was significantly higher in the records from the nasal alae. A sharper waveform is easier to identify. A significant increase in the waveform sharpness may contribute to an easy discrimination of test results (even those of a very small amplitude) from patients with facial nerve palsy.

There was no significant difference in interside variance between the two recording methods in normal group. The mean interside variance was 19.3 per cent (range 0.3–33.9 per cent) on the nasolabial folds and 20.9 per cent (1.1–39.9 per cent) on the nasal alae. Esslen *et al.* reported an interside variance of three per cent, and several other authors have also reported an interside variance of around 20 per cent.[1,10]

To obtain the test-retest variability, the tests were repeated at an average of 4.6 days after the first recording in the normal group. There was also no significant difference in the test-retest variability between the two recording methods (nasolabial fold: 20.6 per cent, nasal ala: 21 per cent). Test-retest variability is one of the important factors in assessing ENoG recordings.[11] Hughes *et al.* reported a test-retest variability of 11.8 per cent, and mentioned that it is of great importance especially in patients with facial nerve palsy where serial recordings influence the future outcome and therapeutic planning.[6,12]

Conclusion

There was no significant difference between the two different electrode placements in the amplitude of the waveform, interside difference, and test-retest variability, which are considered to affect the result. When interpreting the results of ENoG, there was no significant difference between the two electrode positions. However, when the electrodes were placed on the nasal ala, the supramaximal threshold was significantly lower, making a fast recording with a less painful stimulus. Moreover, the ideal biphasic configuration was present in almost all cases with fewer artifacts. A significant increase in the waveform sharpness may contribute to an easy discrimination of test results from patients with facial nerve palsy when electrodes are placed on the nasal alae. Therefore, it is thought that placing the recording electrode on the nasal ala would be the preferred method.

References

1 Kartush JM, Lilly DJ, Kemink JL. Facial electroneurography: clinical and experimental investigations. *Otolaryngol Head Neck Surg* 1985;**93**:516–23
2 May M, Klein SR, Blumenthal F. Evoked electromyography and idiopathic facial paralysis. *Otolaryngol Head Neck Surg* 1983;**91**:678–85
3 Dennis JM, Coker NJ. Electroneuronography. *Adv Otorhinolaryngol* 1997;**53**:112–31
4 Gutnick HN, Kelleher MJ, Prass RL. A model of waveform reliability in facial nerve electroneurography. *Otolaryngol Head Neck Surg* 1990;**103**:344–50
5 Gantz BJ, Gmuer AA, Holliday M, Fisch U. Electroneurographic evaluation of the facial nerve. Method and technical problems. *Ann Otol Rhinol Laryngol* 1984;**93**:394–8
6 Hughes GB, Josey AF, Glasscock ME, Jackson CG, Ray WA, Sismanis A. Clinical electroneurography: statistical analysis of controlled measures in twenty-two normal subjects. *Laryngoscope* 1981;**91**:1834–46
7 Neuwirth-Riedl K, Burian M, Nekahm D, Gstottner W. Optimizing of electroneuronography of the facial nerve. *ORL J Otorhinolaryngol Relat Spec* 1990;**52**:360–7
8 Redhead J, Mugliston T. Facial electroneuronography: action potential amplitude and latency studies in 50 normal subjects. *J Laryngol Otol* 1985;**99**:369–72
9 Coker NJ. Facial electroneurography: analysis of techniques and correlation with degenerating motorneurons. *Laryngoscope* 1992;**102**:747–59
10 Raslan WF, Wiet R, Zealear DL. A statistical study of ENoG test error. *Laryngoscope* 1988;**98**:891–3
11 Sittel C, Guntinas-Lichius O, Streppel M, Stennert E. Variability of repeated facial nerve electroneurography in healthy subjects. *Laryngoscope* 1998;**108**:1177–80
12 Hughes GB, Nodar RH, Williams GW. Analysis of test-retest variability in facial electroneurography. *Otolaryngol Head Neck Surg* 1983;**91**:290–3

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