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CNP is affected by the chewing strength —Pattern of the appearance of masticatory masseter electric discharge—

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Abstract To determine whether cortical negative potential (hereafter referred to as CNP), which was recorded from the scalp (sites: T3, CZ and T4), preceding the right-side chewing, is affected by the pattern of the appearance of masseter electric discharge, difference of strong and weak chewing with CNP appearance were compared. In the case of strong chewing, CNP appeared early, and its amplitude increased as compared with the results in the case of weak chewing. From this result, we related that CNP amplitude is related to the chewing output.

Key words
Chewing motion,
Cortical negative potential,
Electromyogram

Introduction

The cortical negative potential (hereafter referred to as CNP) recorded from the human scalp is also referred to as movement-related cortical potential (hereafter referred to as MRCP)[1–17], and reflects the preparatory state of the brain for movement. On the basis of the distribution of its appearance, MRCP in the cerebral cortex was reported to be related to the limb movement and body area localization[4,7]. Many reports on MRCP are related to its relationships with the upper and lower limb movements[5–18]. There are few reports on the closing movement of the jaw (chewing motion)[1–4].

Vaughan *et al.*[4] also determined CNP during the chewing motion as MRCP because it is related to movement. They reported that this MRCP is recorded from an outside lateral area corresponding to hand motor function. However, they observed CNP only in one hemisphere, and did not investigate the distribution of CNP appearance in the entire brain in detail.

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Nakajima *et al.*[1,2] compared the distributions of CNP appearance ipsilateral and contralateral to the chewing side and reported that the ipsilateral distribution of CNP appearance is predominant. Tanaka *et al.*[3] recorded the topography of CNP from electrodes placed at 12 sites of the scalp and reported that CNP for the chewing motion is localized to the temporal area ipsilateral to the chewing side 50 to 70 ms before the start of masseter electric discharge.

On the other hand, the chewing motion functions to crush food voluntarily[18]. It is easily conceivable therefore that one's sensation of the periodontal membrane has a great effect on one's occlusion force and chewing force depending on one's dental condition and food characteristics[19].

The relationship between force and CNP amplitude during chewing is yet to be clarified, although a positive correlation between force and CNP amplitude in finger movement was reported[5,8,16,17]. Therefore, the authors investigated changes in CNP appearance associated with chewing in relation with the pattern of appearance of masseter electric discharge.

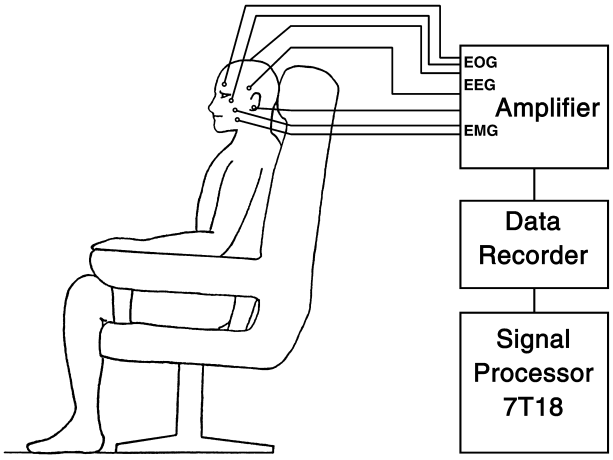

Fig. 1 Experiment block diagram
EOG: electro-oculogram; EEG: electroence-phalogram; EMG: electromyogram

Subjects and Methods

The study subjects were 14 healthy adults (6 males and 8 females) with individual normal dental articulation, who had no history of neuropathy, and who had no stomatognathic function or periodontal tissue abnormalities. All the subjects showed right-side habitual mastication. All the subjects were chosen on the basis of the following criteria: the right maxillary or mandibular region has no tooth defects and the filling, if any, is localized to the pit and fissure. The subjects sat relaxed on an armchair with the facial horizontal (FH) plane nearly parallel to the floor and chewed while gazing at an index positioned 1.5 m in front of them at eye level (Figure 1).

Electroencephalographic recording from the left temporal area (T3), middle-central area (CZ), right temporal area (T4), and bilateral ear lobes was performed using unipolar lead in accordance with the International Potential Method (10–20 methods). Electroophthalmograms were recorded to examine the potential generated by the winking motion, which were also present in electroencephalograms. Electroencephalograms containing this potential were excluded from data analysis. Electromyocardiograms of the masseter were recorded from the skin at the center of the masseter shallow area using bipolar lead. Silver—silver hydrochloride surface electrodes were used to record electroencephalograms, electro-ophthalmograms and electromyocardiograms.

The amplification and recording of electroencephalograms, electroophthalmograms and electromyograms were carried out using the Polygraph 362 system and Rectigraph 8K (NEC San-ei Instruments). These data were simultaneously recorded on 14-ch, Data Recorder XR 510 (TEAC Inc.). The time constants for electroencephalography and electro-ophthalmography were determined as 1.5 s. The time constant for electromyography was determined as 0.01 s. The electromyograms of the masseter on the chewing motion side were subjected to full-wave integral rectification and the result was determined as a CNP trigger pulse. CNP was obtained by 50 times of signal averaging of electroencephalograms, electroophthalmograms and electromyograms for 2 s before and for 1 s after the start of masseter electric discharge, using Signal Processor 7T18 (NEC San-ei Instruments).

The specified motion was the habitual mastication side or the right-side chewing. The subjects chewed quickly once every 3 to 5 s at their own pace, and they were instructed not to move their tongue during chewing. After they had practiced chewing about ten times before the start of the experiments, the subjects carried out two or three trials, each of which consists of chewing 50 times.

Regarding strong and weak chewing, the subjects were instructed to carry out the strongest chewing and we confirmed CNP amplitude at that time on the monitor (oscilloscope) of the electromyogram. Eighty percent and 30% of this amplitude were determined as strong and weak chewing, respectively. The subjects practiced each motion ten times and performed two or three trials, each of which consists of chewing 50 times.

To ensure that all the subjects performed the right-side chewing at a fixed mouth opening, a resin block was used. Hirabayashi *et al.*[20] reported that the maximum articulation force is generated at a mean mouth opening of 10.4 mm at the incisor teeth. On the basis of this report, we prepared resin blocks for fixing the mouth opening (interincisal distance) of 10 mm at the incisor teeth, the articulation load area of which covered the area from the second premolar teeth to the third tooth of the second molar teeth of the right mandible[21]. The method of preparing the resin blocks was as follows. The impressions of the subjects' upper and lower jaws were obtained using an alginic acid impression material. These impressions were mounted on a Whip-Mix articulator in a centric jaw relation. A resin block was then formed on the articulator using

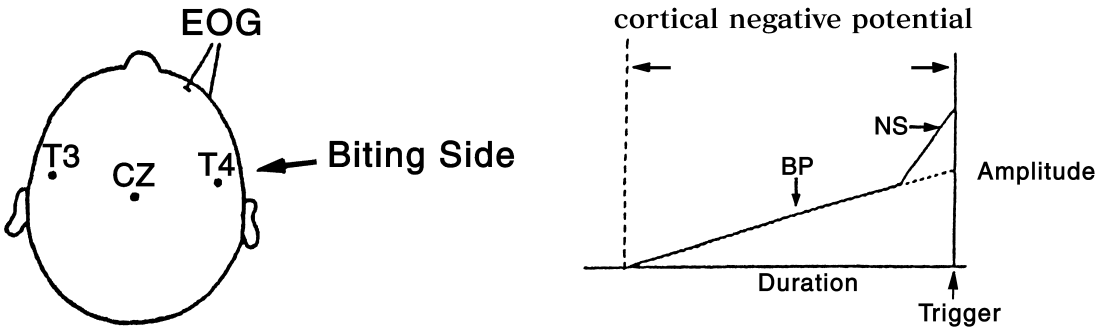

Fig. 2 Pattern of appearance of CNP
T3: left temporal area; CZ: midline-central area; T4: right temporal area; EOG: electro-oculogram; BP: Bereitschaftspotential; NS: negative slope

Table 1 The mean CNP durations and the maximum CNP amplitudes during strong and weak chewing

Sub.	T3		CZ		T4	
	Strong	Weak	Strong	Weak	Strong	Weak
The mean CNP durations ± S.D. (s)	1.45 ± 0.17	1.11 ± 0.26	1.47 ± 0.05	1.17 ± 0.20	1.73 ± 0.18	1.27 ± 0.22
The maximum CNP amplitudes ± S.D. (μV)	4.02 ± 1.04	3.01 ± 0.48	7.79 ± 4.23	4.78 ± 4.14	10.43 ± 0.31	6.63 ± 1.43

Table 2 The mean CNP durations during strong and weak chewing (Wilcoxon *t*-test)

(A) Strong				(B) Weak			
	T3	CZ	T4		T3	CZ	T4
T3		—	**	T3		—	**
CZ	—		**	CZ	—		*
T4	**	**		T4	**	*	

*: $P<0.05$
**: $P<0.01$
—: not significant

Table 3 The mean CNP amplitudes during strong and weak chewing (Wilcoxon *t*-test)

(A) Strong				(B) Weak			
	T3	CZ	T4		T3	CZ	T4
T3		—	**	T3		—	**
CZ	—		**	CZ	—		*
T4	**	**		T4	**	*	

*: $P<0.05$
**: $P<0.01$
—: not significant

instant copolymerization resin.

The CNP factors measured during chewing were CNP duration and maximum potential amplitude. CNP has two components: the Bereitschafts potential (hereafter referred as BP) and negative slope (hereafter referred as NS) that appears after BP (Figure 2), in accordance with the classification by Nakajima *et al.*[2] CNP duration was defined as follows: by setting the mean electroencephalogram before the start of masseter electric discharge as the reference potential (baseline), CNP duration is defined as the time difference between the

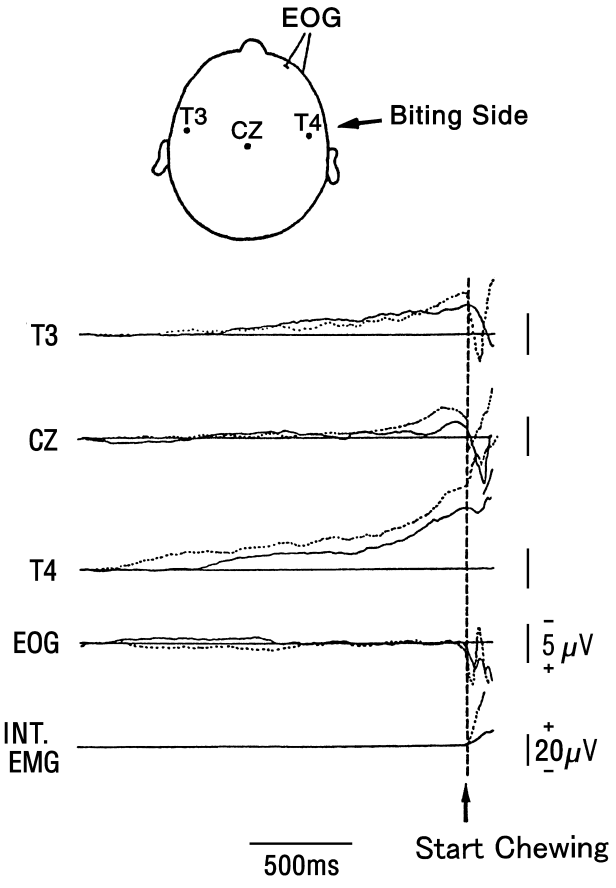

Fig. 3 Pattern of appearance of CNP associated with strong and weak right-side chewing

The solid line denotes data for weak chewing, and the dotted line, data for strong chewing. The other signs are the same as those in Figure 2.

appearance of scalp surface negative potential from the baseline and the start of electric discharge from the right masseter. The maximum CNP amplitude at each recording site was obtained by calculating the peaks of BP and NS generated from the baseline to the start of electric discharge from the right masseter, according to the method of Nakajima *et al.*[2] CNP duration and maximum CNP amplitude were subjected to Wilcoxon's *t*-test to determine the significance of difference.

Results

Patterns of CNP appearance associated with strong and weak right-side chewing motions

To investigate the relationship between CNP and masseter electric discharge in detail in view of the increased CNP amplitude after the anesthetization with a sharp initial rise slope of masseter electric discharge, 14 subjects were instructed to perform strong and weak right-side chewing motions, and the results were assessed. The mean CNP durations during strong and weak chewing in the 14 subjects were 1.45 ± 0.17 s and 1.11 ± 0.26 s at T3, 1.47 ± 0.05 s and 1.17 ± 0.20 s at CZ, and 1.73 ± 0.18 s and 1.27 ± 0.22 s at T4, respectively. The maximum CNP amplitudes during strong and weak chewing were $4.02 \pm 1.04\mu$V and $3.01 \pm 0.48\mu$V at T3 (NS and BP), $7.79 \pm 4.23\mu$V and $4.78 \pm 4.14\mu$V at CZ (BP), and $10.43 \pm 0.31\mu$V and $6.63 \pm 1.43\mu$V at T4 (NS), respectively (Table 1). And the mean CNP durations and The maximum CNP amplitudes during strong and weak chewing with wilcoxon *t*-test (Tables 2 and 3).

Typical results are shown in Figure 3. When the subject chewed weakly, the longest CNP duration of 1.52 s was observed at T4, while the shortest CNP duration of 1.39 s was observed at CZ. NS at T4 showed the largest amplitude of 7.69μV, whereas BP at CZ showed the smallest amplitude of 1.92μV. When the subjects chewed strongly, the longest CNP duration of 1.88 s was observed at T4, while the shortest CNP duration of 1.44 s was observed at CZ. NS at T4 showed the largest amplitude of 10.30μV, whereas BP at CZ showed the smallest amplitude of 4.04μV. Regarding the initial increases in electromyograms associated with strong and weak chewing motions, the initial increase during strong chewing was sharper with a higher potential than that during weak chewing. In the case of weak chewing, the initial increase in masseter electric discharge was gradual. Similar results were also observed in the other 13 subjects.

Discussion

Patterns of CNP appearances before and after anesthetization CNP was recorded in the bilateral temporal areas (T3 and T4) and the midline central area (CZ) from 1 to 2 s preceding a voluntary chewing motion. CNP showing the largest amplitude appeared in the temporal area on the chewing side (T4). These findings were in agreement with those reported by Nakajima *et al.*[1,2] and Tanaka *et al.*[3] Moreover, Shibasaki *et al.*[10,11] referred to CNP as movement-related cortical potential and divided it into two components, BP and NS. NS is related to

finger movement and is localized to the center or the contralateral side (of the cerebral cortex). NS has therefore been considered to be generated in an area directly related to finger movement[10,11]. Evarts[22] reported on the basis of records from monkey brains obtained using microelectrodes that pyramidal cells became active from 60 to 100 ms before the start of masseter electric discharge during wrist movement. Nakajima *et al.*[2] considered that because NS appearance in the temporal area on the side ipsilateral to the chewing side was observed from 70 to 80 ms before the start of masseter electric discharge, NS reflected neuron activity in the area directly related to the chewing motion. It was also identified that NS amplitude and the rate of NS appearance were ipsilaterally dominant[2].

Relationship of strong and weak chewing with CNP appearance, in the case of strong chewing, the CNP duration in the ipsilateral temporal area was particularly long, NS increased rapidly immediately before masseter electric discharge, the NS amplitude was greater than those in the other recording sites, and the initial increase in masseter electric discharge was sharp. In the case of weak chewing, NS amplitudes decreased, and the initial increase in masseter electric discharge was gradual. (Tables 1, 2 and 3)

Washimi *et al.*[15] investigated the relationship between the rate of change in the force of ankle dorsiflexion and CNP from the motor area of the feet. They reported that NS amplitude increased as the initial increase in masseter electric discharge subjected to full-wave rectification integration was sharper.

A positive correlation between force and CNP amplitude during hand movement was demonstrated[5,8,9,16,17]. Becker *et al.*[9] reported that when subjects were instructed to perform strong and weak isometric movements of their right forefingers, in the case of a large force, CNP amplitude increased significantly at C3, C4 and CZ, that is, hand motor areas. In addition, when a large force was exerted, CNP distribution was not asymmetric, and cortical activity in the bilateral motor areas was detected.

The appearances of NS in the right and left temporal areas, which was particularly marked on the ipsilateral side, in association with strong chewing in the present study were similar to the above-mentioned reports on the hand.

The above findings suggest that in the case of strong chewing, neuronal activity in the ipsilateral chewing area (T4) increased as compared with that in the case of weak chewing.

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