NEURAL DESCENDING PATHWAYS FROM
THE CORTICAL JAW MOTOR AREA
AND AMYGDALOYD NUCLEUS TO JAW MUSCLES*

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Previously1), we have determined the various jaw movements of rabbits that
can be evoked by electrical stimulation of the cortical jaw motor region. Jaw
movement induced by stimulation of the neocortical jaw motor region was pre-
dominant in a jaw opening direction whereas that following stimulation of the
amygdala was predominant in a jaw closing direction. Additionally, these two
brain regions could induce jaw movements independently.

In this experiment, the representation in these brain structures of each jaw
muscle and the descending neural pathways from the neocortex and amygdaloid
nucleus concerned with jaw movement were explored physiologically.

METHODS

Fourteen adult rabbits were used. The experimental procedures were quite
similar to those reported in the previous paper. But in this experiment, the brain
was stimulated, point to point, by a single shock and the evoked single contraction
of the digastric muscle (the jaw opening muscle) and masseter (the jaw closing
muscle) was recorded by means of an electromyogram. For stimulation bipolar
stainless steel electrodes, about 150 µ in total diameter, insulated except at the
tip were used. A rectangular single shock of 10-15 volts (threshold intensity)
of 1 to 2 msec. duration was applied to elicit a single contraction of the jaw
muscle. An insulated copper wire (200 µ in diameter) was implanted into each
muscle as an electrode to record the electromyogram and a 5 stage conventional
resistance-capacity coupled amplifier and a cathode ray oscillograph were used. In
order to establish the descending neural pathways, in some experiments, the
response was recorded in some animals after either ablation of the unilateral
neocortical jaw motor area, electrocoagulation of the cerebral peduncles, or
transection of the mesencephalon and diencephalon.

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** Appointment, Appendix
The sites of stimulation and destruction of the brain were verified histologically.

RESULTS

(1) Stimulation of the brain

With a single shock given to a unilateral cortical jaw motor area, a response with latency of 8.5 to 9.0 msec. was clearly recorded bilaterally from the digastric muscles, but the responses could not be recorded from the masseters on either side (Fig. 1). The response of the digastric was a little greater in amplitude on the stimulated side than the contralateral side, but the latencies were almost the same on both sides.

In the case of stimulation on the ventro-medial part of the unilateral internal capsule, bilateral responses of the digastric were evoked with latencies of 8.0 to 8.5 msec., the response being a little greater in amplitude on the side ipsilateral to the site of stimulation (Fig. 2).

Fig. 1. (Left) Electromyographic responses of jaw muscles from the right cortical jaw motor area.

Fig. 2. (Right) Electromyographic responses of jaw muscles from the right internal capsule.

Following unilateral stimulation of the subthalamus, the digastric muscles responded bilaterally with latencies of about 8.0 msec., the response on the stimulated side being greater in amplitude than that of the contralateral side. But no
Fig. 3. (Left) Electromyographic responses of jaw muscles from the right subthalamus.

Fig. 4. (Right) Electromyographic responses of jaw muscles from the left lateral amygdaloid nucleus.

Fig. 5. Electromyographic responses of jaw muscles from the left mesencephalic reticular formation.
responses were observed in the masseter on either side (Fig. 3).

A single shock applied unilaterally to the lateral nucleus of the amygdaloid complex induced only a response in the ipsilateral masseter with a latency of about 15.0 msec. and it did not evoke any responses from the other muscles (i.e., contralateral masseter or either digastric muscle). (Fig. 4).

A point in the unilateral mesencephalic reticular formation, about 7.0 to 9.0 mm in depth from the dorsal surface of the brain, induced a response with a latency of 11.5 to 13.0 msec. only in the ipsilateral masseter, and not in any other jaw muscle. From points about 10.0 to 11.0 mm in depth from the dorsal brain surface the both digastrics responded with latencies of 3.0 to 4.5 msec. The amplitude of the response in the ipsilateral digastric was a little greater than that of the other. In this case, however, no response was detected in the masseter (Fig. 5).

By stimulation of the unilateral trigeminal motor nucleus, both digastrics and masseters responded bilaterally with latencies of 2.5 to 3.0 msec., but the

![Fig. 6. (Left) Electromyographic responses of jaw muscles from the left trigeminal motor nucleus.](image)

![Fig. 7. (Right) Effects of electrocoagulation of the cerebral peduncles on cortically evoked jaw responses.](image)

R: stimulated side  L: contralateral side
amplitude of this response was a little smaller in the contralateral side compared to the ipsilateral side (Fig. 6).

(II) Destruction of the brain

Even after bilateral electrocoagulation of the cerebral peduncles, the responses of both digastrics to the cortical jaw motor area stimulation were not affected at all (Fig. 7).

After unilateral ablation of the cortical jaw motor area, the response of the digastric muscle induced by stimulation of the remaining jaw motor area was similar to that of the normal unablated control, but the response of the contralateral side was somewhat smaller in amplitude. The threshold of the stimulation to induce this response, however, increased a little on both sides (Fig. 8).

A longitudinal section of the brain up to the caudal level of the subthalamus was performed in addition to unilateral destruction of the cortical jaw motor area. After this treatment the responses induced by stimulation of the cortical jaw motor area of the intact side did not show any remarkable change in either of the biventer sarcomeres compared to that taken before this treatment. Even after extending this longitudinal section to the caudal level of the mesencephalic reticular formation, the response of this muscle did not change in its latency, but the amplitude of the response decreased remarkably on the same side as the lesion (Fig. 9).
SHERRINGTON\(^2\) stated that the function of jaw opening has a large representation in the cortex and RIOCH\(^3\) reported that stimulation of the cortex excites the jaw opening muscles and relaxes the jaw closers. Previously we also demonstrated that jaw movement induced from the cortical jaw motor area was predominant in the opening direction, whereas that induced from the amygdala was predominant in the closing direction\(^1\). RUCH et al.\(^4\) stated that the extensors have more cortical representations than the flexors and distal muscles more than the proximal ones. Following our previous experiment, it is assumed that the digastric muscle (jaw opening muscle) corresponds to the extensor and the masseter to the flexor\(^5\). Our present results also mean that the cortical jaw motor area predominantly innervates the jaw opening muscles (digastric muscles). However, PENFIELD and BOLDREY\(^6\) reported that on stimulating the human cerebral cortex, points for jaw closing as well as for jaw opening were found to exist in the precentral and postcentral region. The significance of this difference between various animal species must be studied further.

On the other hand, stimulation of the lateral amygdaloid nucleus or dorsal part of the mesencephalic reticular formation produced responses of the masseter on the stimulated side only, indicating that the amygdala and mesencephalic reticular formation innervate only the ipsilateral masseters. This evidence is well in accordance with our previous report\(^1\) showing that jaw movement induced from

R: contralateral side  L: stimulated side
the amygdala is predominant in the closing direction. This is also supported by
the report of WOOD et al.\textsuperscript{7} confirming that stimulation of the ventral portion of
the lateral amygdaloid nucleus produces only jaw closure. However, they have
indicated that sustained jaw opening and closing was induced from the basal
medial amygdaloid nucleus, but in our experiments a single contraction of the jaw
openers could not be obtained by stimulation of the amygdaloid complex.

The responses of the digastric induced by stimulation of the cortex have
shorter latencies than those of the masseter induced from the amygdala. There-
fore, it is considered that these two pathways are different from each other and
the latter has more neural stations on its way to the trigeminal motor nucleus.

The descending pathway from the cortex for mastication has been studied
by many workers\textsuperscript{3,8,9,10,11). This pathway for mastication was first traced through
the internal capsule by R\textsuperscript{é}THI\textsuperscript{8}) in the rabbit. On the other hand, CARPENTER\textsuperscript{9})
followed the tracts into the medial portion of the crus cerebri in the rabbit.
MILLER\textsuperscript{10} and also RIOCH\textsuperscript{3}) reported that the infracortical tract for mastication
and deglution could be traced through the lower part of the internal capsule in the
rabbit. MAGOUN et al.\textsuperscript{11}) stated that the corticofugal pathway for mastication could
be traced in the internal capsule and cerebral peduncle to the extreme caudal end
of the pons in the cat. But there are many opinions as to the descending course
of this corticofugal pathway from the internal capsule.

R\textsuperscript{é}THI\textsuperscript{8}) postulated that there may be an intercalary center in either the
diencephalon or upper part of the mid-brain, and ECONOMO\textsuperscript{12}) and BECHTEREW\textsuperscript{13})
agreed with this opinion when they postulated that the substantia nigra was a
special intercalary center for masticatory movement. However, this concept was
denied following the experiments of MILLER\textsuperscript{10} and MAGOUN et al.\textsuperscript{11}). MAGOUN
et al. have shown that the corticofugal pathway for lapping movements in cats
reaches the homolateral trigeminal motor nucleus without decussation. RIOCH\textsuperscript{3})
also expresses essentially the same opinion as MAGOUN et al.

HIRAYAMA\textsuperscript{14}) asserted that the pathway for jaw movement from the cortex
was via the homolateral thalamus and passed through the contralateral motor
nucleus of the fifth nerve in the dog. HIRASAWA\textsuperscript{15}), studying the descending anatom-
ical pathways from the cortex, classified the cortical extrapyramidal tracts into
five categories, one of them being via the thalamus on its way to the tegmentum
of the mid-brain. In addition, IMOGAWA and SAKUMA\textsuperscript{16,17}) traced the degeneration
resulting from destruction of anterior and posterior parts of the lateral surface of
the cortex of the rabbit and declared that it could be followed to the basal ganglia,
thalamus and nigral substance. Physiologically, FRENCH et al. also\textsuperscript{18}) confirmed
by means of evoked potentials that there were projections from the cortex to
the subthalamus and mesencephalic reticular formation in the cat. Further, HESS
and MAGNUS\textsuperscript{19}) have recognized that mastication and lapping are induced by
stimulation of the ventral thalamus. Also in our previous experiments rhythmic
jaw movements were obtained by stimulation of the subthalamus. Therefore, it
is assumed that there is an intercalary center in the subthalamus along this pathway.

In the present experiment responses of the digastric were induced bilaterally by single shock to either of the cortical jaw motor areas, internal capsule, subthalamus or deeper parts of the mesencephalic reticular formation. Even after bilateral destruction of the cerebral peduncles, these responses of the digastric induced from the cortex were not affected. Hence, the corticofugal pathway for jaw movement is assumed to have some intercalary center in subthalamic region and not to descend through the cerebral peduncles.

As to decussation of the descending pathway from the cortical jaw motor area for mastication, SHERRINGTON2) stated that the jaw muscles were innervated unilaterally by the contralateral cortical jaw motor area in the cat and MILLER10) and RIOCH5) reported that mastication movements induced by the stimulation of the cerebral cortex of the rabbit were bilateral. But MAGOUN et al.,11) declared that the pathway from the cortical jaw motor area reached ipsilaterally to the trigeminal motor nucleus without any decussation in the cat. HIRAYAMA14) postulated a unilateral projection for mastication and the existence of a decussation at the level of the mid-brain in the dog. However, according to our present results, it is considered that there are two corticofugal pathways for mastication. Both of them have an intercalary center in the region described above and from this center one pathway descends to the ipsilateral trigeminal motor nucleus, while the other decussates in the mesencephalic reticular formation and descends to the contralateral trigeminal motor nucleus.

The descending pathways from the amygdala have been explored anatomically by JOHNSTON20), YOUNG21) and Fox22), but the functions of these pathways are not yet well determined. HIRASAWA15) claimed the possible existence of some motor pathway for feeding reactions which arose from the olfactory bulb and went to the tegmentum of the brain stem via the amygdala. Moreover, recently GLOOR23) and BUCHWALD and ERVIN24) reported responses with short latencies in the tegmentum resulting from stimulation of the lateral nucleus of the amygdala. Although no direct projections from the lateral nucleus of amygdala to the tegmentum of the mid-brain in mammals have been postulated morphologically, the present results also show the existence of a pathway from the lateral nucleus of amygdala to the trigeminal motor nucleus via the mesencephalic reticular formation.

SUMMARY

In this experiment, the physiological function of the neocortical jaw motor area and amygdaloid nucleus in relation to jaw movement were studied in the rabbits.

1. By single unilateral shock to either of the cortical jaw motor areas, internal capsule, subthalamus or deeper part of mesencephalic reticular formation, the digastric muscles showed marked bilateral electromyographic responses. However,
the masseter did not respond at all.

2. The corticofugal pathway for jaw movement was found to have an intercalary center in the subthalamic region after passing through the internal capsule. This pathway may have a decussation at the level of mesencephalic reticular formation.

3. Following stimulation of either the lateral amygdaloid nucleus or dorsal part of the mesencephalic reticular formation only the ipsilateral masseter responded electromyographically.

4. The descending pathway from the amygdala is considered to play a predominant part in closing the jaw and that from the cortex is assumed to be the one for opening the jaw.

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REFERENCES


