EVOKED POTENTIALS RECORDED IN OCULOMOTOR NUCLEI AND THEIR NEIGHBOURHOOD BY ANTERIOR AMPULLARY NERVE STIMULATION : Especially Concerning Vestibular Eye Movements

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EVOKED POTENTIALS RECORDED IN OCULOMOTOR NUCLEI AND THEIR NEIGHBOURHOOD BY ANTERIOR AMPULLARY NERVE STIMULATION

—Especially Concerning Vestibular Eye Movements—

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Mutsuo AMATSU. *Evoked Potentials Recorded in Oculomotor Nuclei and their Neighbourhood by Anterior Ampullary Nerve Stimulation.* Kobe J. Med. Sci. 12, 231-241, December 1966——Anterior ampullary nerve was stimulated by single shock and repetitive shocks in order to observe the brainstem activity during the vestibular eye movements and evoked potentials were recorded in oculomotor nuclei and their neighbourhood. Remarkable difference was observed in oculomotor nucleus evoked potentials between single shock and repetitive stimulation of anterior ampullary nerve which induced eye movements. Remarkable negative wave was recorded in about 7 m. sec. latency during the eye movements and for a while after cessation of eye movements by repetitive stimulation. This negative wave did not appear, when muscle relaxants were used intravenously and topically.

From the results above described afferent connections between extraocular muscle and brainstem were concluded.

INTRODUCTION

It is now the obvious fact that semicircular canal stimulation causes eye movement. Furthermore individual semicircular canal connections to corresponding extraocular muscles and directions of the eye movements are clarified to great extent (Szentagothai,[16] Fluur,[11] Cohen et al[2-4]). Recent electrophysiological works demonstrate the eys muscle sensory endings, although cat's extraocular muscle lacks in mucle spindles. (Cooper et al,[5-9] Filenz,[10] Kumoi[12]). These works strongly suggest the afferent connection between extraocular muscle and brainstem, while brainstem activity during the vestivular eye movements has been yet unclarified.

This paper has two purposes: to decide which side of oculomotor nucleus is closely related to anterior semicircular canal and to clarify the afferent connections between extraocular muscles and brain stem during vestibular eye movements.

METHODS AND MATERIALS

These experiments were performed under intraperitoneal nembutal anesthesia (35 mg/kg) using adult cats weighing more than 2.5 kg. The cats were prepared with tracheotomy and saphenous vein canulization for adminstration of drug. Using

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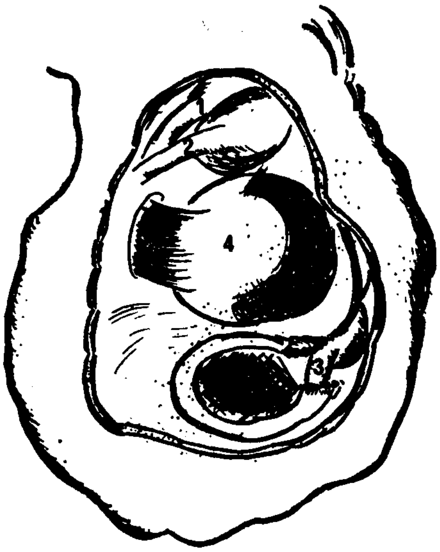
the surgical approach described by Szentagothai, S. Anderson and B. E. Gernandt,[1] after the mastoid process was opened and bony labyrinth was destroyed through the round window, the anterior ampullary nerve coming from the anterior canal on the left side was prepared for stimulation. (Fig. 1) A silver bipolar electodes (100 μ in diameter) were hooked around the anterior ampullary nerve and fixed in place



Vestibular nerve branches from the ampulla of the

Anterior canal	1
Lateral canal	2
Posterior canal	3
and	
Utricle	4

Fig. 1 Ventrolateral view of the left vestibule

with dental cement.[12] Utricular nerve, lateral ampullary nerve and facial nerve were removed beforehand. If necessary, superior rectus branch and inferior oblique branch of both sides were exposed and stimulated antidromically with same electrodes as ampullary nerve stimulation. Precollicular transection was performed and cerebellum was sucked off. Care was taken to avoid damage of cranial nerves. According to the Atlas (Snider[15]), a needle electrode (10 20μ in diameter) was penetrated to oculomotor nuclei and their neighbourhood to record evoked potentials. The ampullary nerve and oculomotor nerve branches were stimulated by electronic stimulater (Nihon Kohden K-K model MSE-3) which delivered square wave shocks once, 50 times and 100 times every second through isolation unit.

These shocks had a duration of 0.05 m. sec. or 0.2 m. sec. and ranged in in intensity from 2 to 6 V.

Potential change was recorded consecutively as shown in Fig. 5 and 6 till 300 seconds during repetitive stimulation. Evoked potential was recorded through amplifier (Nihon Kohden K-K model AVB-I) and displayed on an cathode ray oscilloscope (Nihon Kohden K-K model-VC-6), then photographed with long recording camera (Cannon Photo Oscilloscope Unit model IV). At the end of experiment recording electrode was remained and the tip of the electrode was checked by serial sectioning of the fixed brain.

RESUTS

Single shock stimulation of the left anterior ampullary nerve did not elicit eye movements, while the repetitive stimulation (a duration of 0.2 m. sec., especially 100 cps.) caused eye movements shown in Fig. 2.

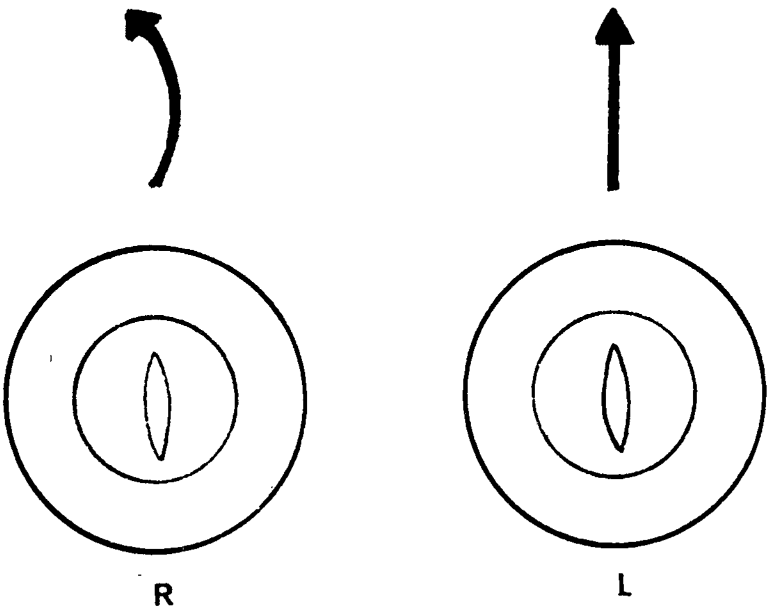


Fig. 2 Eye movements elicited by left anterior nerve repetitive stimulation.

The left eye gradually moved upwards and the right eye showed counter-clockwise rotation. It took usually from 10 to 15 seconds for the eyes to be fixed at steady state. After the eyes were at steady state no movements were occured during long lasting stimulation such as 5-30 minutes.

According to the eye movements shown in Fig. 2, superior rectus branch and inferior oblique branch of the oculomotor nerve were concerned.

Superior rectus branch and inferior oblique branch were stimulated antidromically in both sides and antidromic evoked potentials (latency about 0.5 m. sec.) were recorded systematically in oculomotor nuclei and their neighbourhood in order to determine an active center of electric field. Each potential pair shown in Fig. 3 is composed of evoked potentials recorded in an active center of antidromic electric field by stimulating superior rectus and inferior oblique branch (lower traces of each column) and by stimulating left anterior ampullary nerve (upper traces of each column). An active center by left superior rectus branch stimulation was in right oculomotor nucleus (A-2) and right branch in left nucleus (C-2).

An active center by left inferior oblique branch stimulation, however, was in left oculomotor nucleus (B-2) and right branch in right nucleus (D-2). The potentials evoked in the oculomotor nuclei by stimulating left anterior ampullary

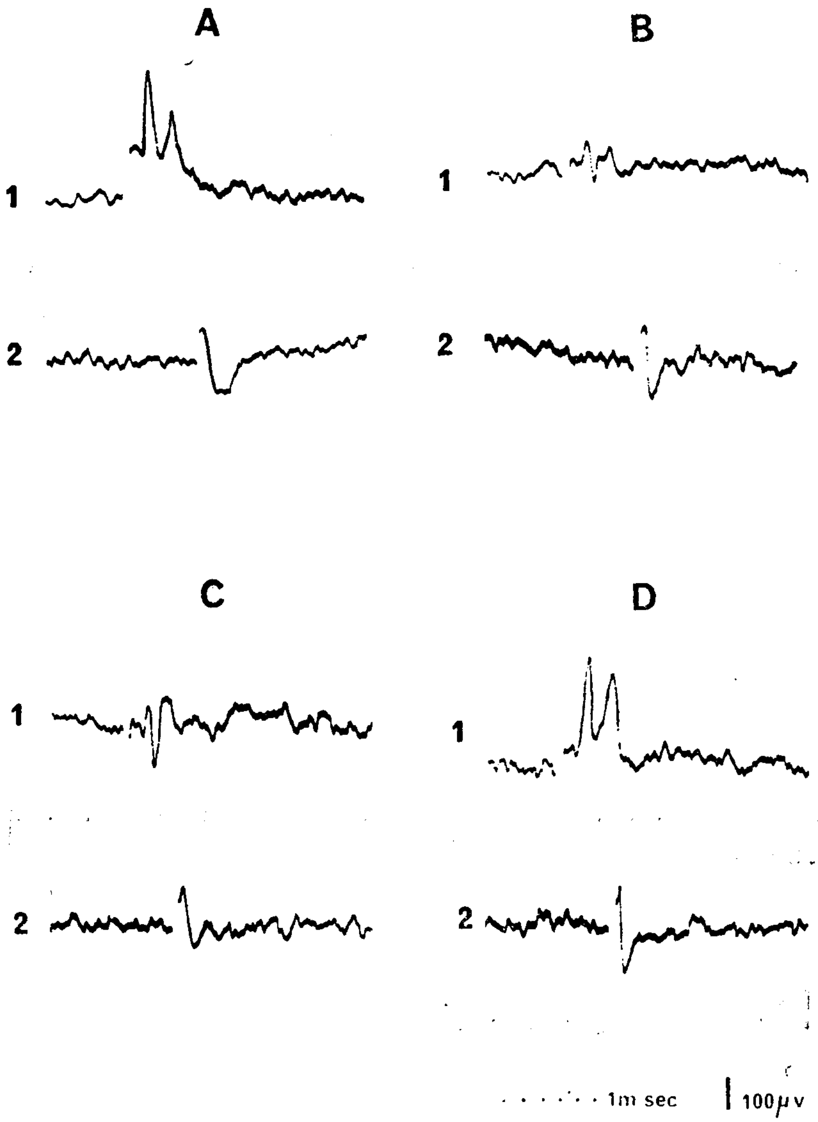


Fig. 3 Evoked potentials in oculomotor nuclei. Each potential pair is composed of evoked potentials by left anterior ampullary nerve stimulation (upper traces) and antidromic stimulation of oculomotor nerve branches (lower traces).

Lower traces: evoked potentials by antidromic stimulation of oculomotor nerve branch obtained in each active center of electric field in oculomotor nuclei. A-2 : by stimulating left superior rectus branch obtained in right oculomotor nucleus. B-2 : by stimulating left inferior oblique branch obtained in left oculomotor nucleus. C-2 : by right superior rectus branch obtained in left oculomotor nucleus. D-2 : by right inferior oblique branch obtained in right oculomotor nuclei.

nerve were negative waves which usually had two components as shown in Fig. 3 (upper traces of each column). The first component had a latency period of 1.5–1.8 m. sec. and a amplitude of 0.2 mv–0.3 mv. The second component had a latency of 2.7–3.0 m. sec. The total duration of the response was from 4 to 5 m. sec.

The large evoked potentials by stimulating left anterior ampullary nerve were recorded in an active center of left superior rectus and right inferior oblique branch stimulation which were in right oculomotor nucleus, (Fig. 3 A-1 and D-1), while the small potentials were evoked in an active center of right superior rectus and left inferior branch stimulation which were in left oculomotor nucleus. (Fig. 3 B-1 and C-1)

Evoked potentials recorded in the oculomotor nuclei at the depth of 7 mm, 0.5 mm from midline, 1 mm intervals from anteriorly to posteriorly by stimulating left anterior ampullary nerve were illustrated in Fig. 4. Large potentials were evoked in right oculomotor nucleus (Fig. 4 B-4, 5). From the results of

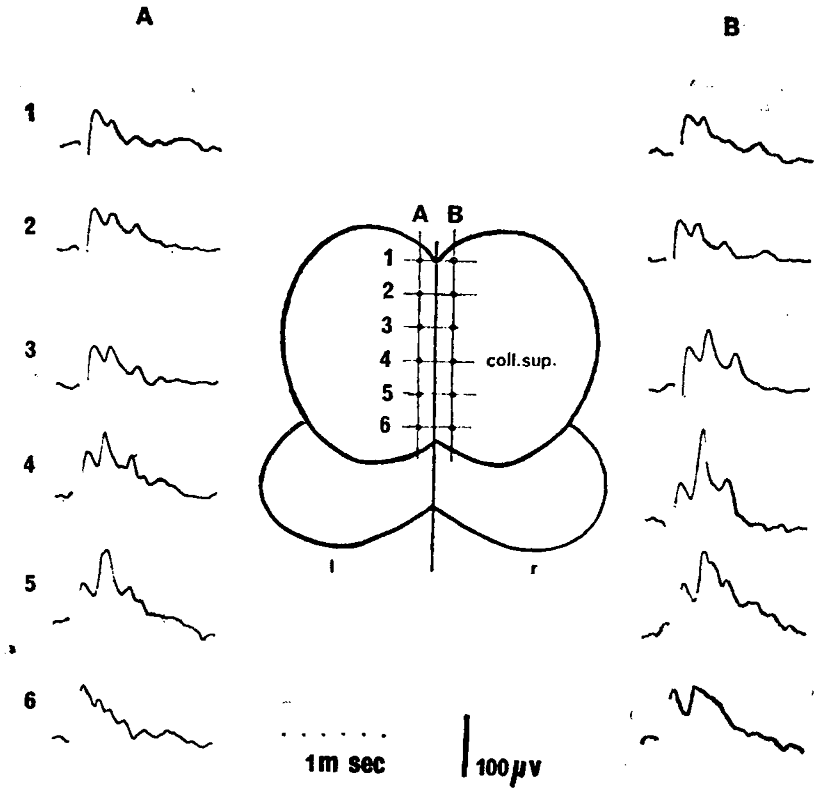


Fig. 4 Oculomotor nuclei evoked potentials by stimulating left anterior ampullary nerve. Column A and B : 0.5 mm from midline, 1 mm step anteriorly to posteriorly, 7 mm depth from surface. Potentials shown in B-4, 5 (in right oculomotor nucleus) are larger than shown in A-4, 5 (in left oculomotor nucleus).

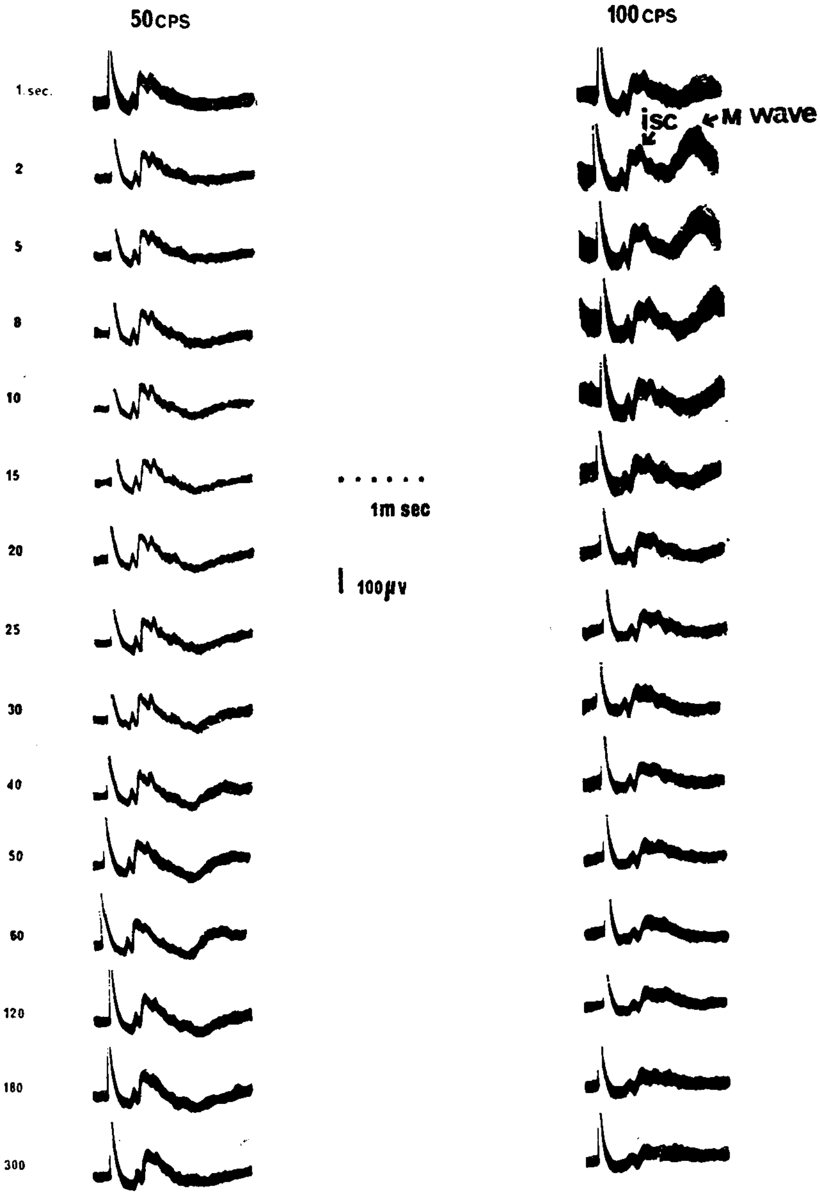


Fig. 5 Evoked potentials by repetitive stimulation of left anterior ampullary nerve recorded in right oculomotor nucleus.

Left column shows 50 cps. stimulation. Right column shows 100 cps. stimulation. Numbers in the left side shows the time after the onset of stimulation. By 100 cps. stimulation of left anterior ampullary nerve remarkable negative wave (indicated by arrow) was seen with latency of about 7 m. sec. and disappeared after 15–20 sec. repetitive stimulation.

Abbreviation. isc : initial spike complex

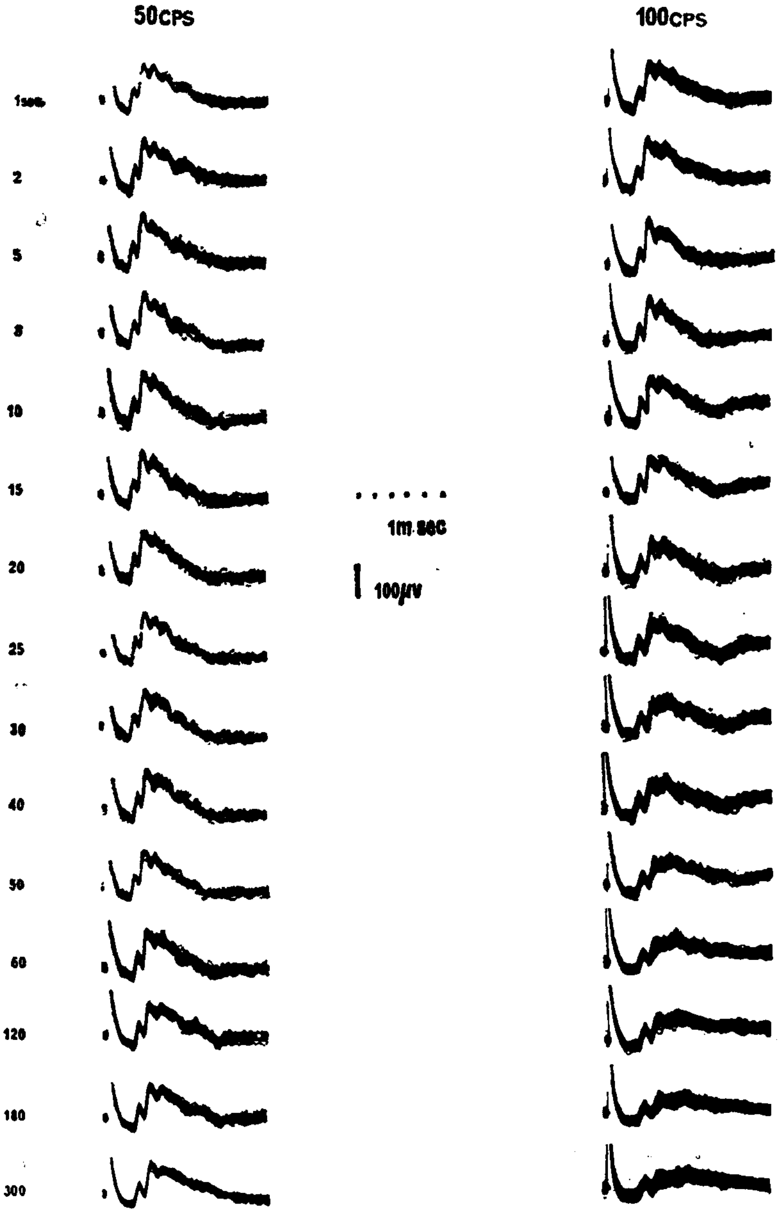


Fig. 6 Evoked potentials recorded at the same point of experiment shown in Fig 5 by stimulating left anterior ampullary nerve, after muscle relaxant was used intravenously to immobilize the extraocular muscle.

experiments illustrated in Fig. 3, and Fig. 4 it seems likely that the left anterior ampullary nerve had close neuronal connection to the left superior rectus branch and right inferior oblique branch of oculomotor nerve which originated from right oculomotor nucleus.

As stated before single shock stimulation of the left anterior ampullary nerve did not elicit eye movements, while repetitive stimulation, especially 100 cps., of the left anterior ampullar nerve produced eye movements shown in Fig. 2.

Evoked potentials in response to 50 cps. and 100 cps. stimulation of left anterior ampullary nerve were recorded in right oculomotor nucleus in which the active center of left anterior ampullary nerve stimulation exsisted and consecutive observation was made till 300 seconds as shown in Fig. 5. Remarkable negative wave was seen

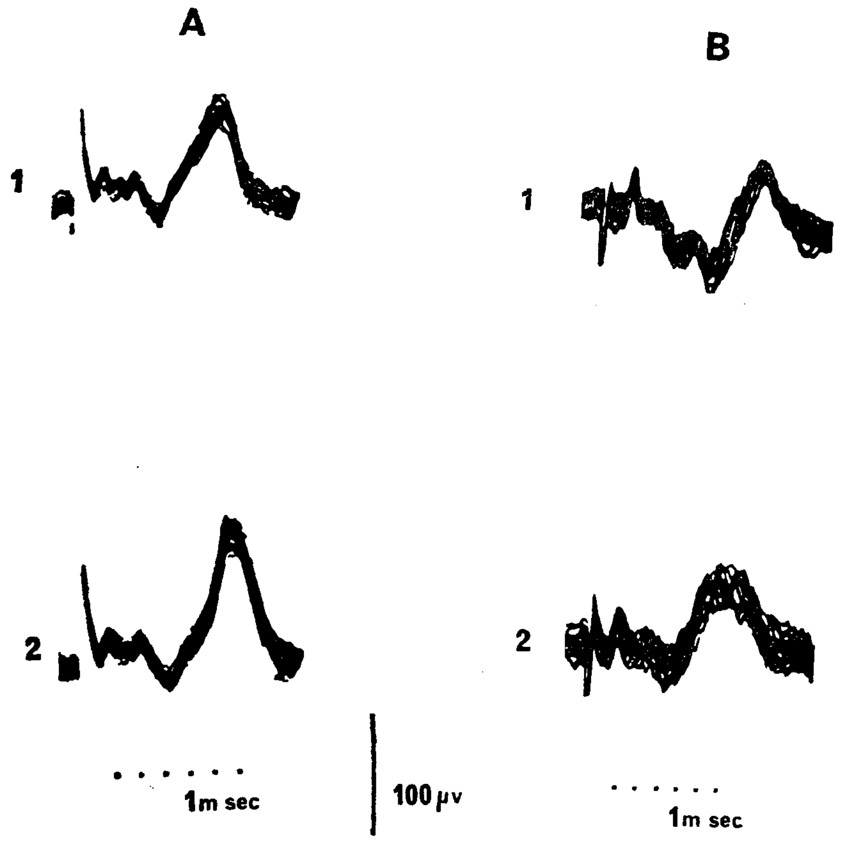


Fig. 7 Evoked potentials recorded in right oculomotor nucleus by stimulating left anterior ampullary nerve.

A-1 : potential before N. opticus was cut off at both sides.
A-2 : potentials after N. opticus was cut off at both sides.
B-1 : potentials before N. ophthalmica was cut off at both sides.
B-2 : potentials after N. ophthalmica was cut off.

especially in 100 cps. stimulation which caused full eye movements. This negative wave was designated as M wave. M wave had about 7 m sec. latency from shock artefact to peak and an amplitude of 0.2 mV in its maximum. Total duration was about from 4 to 5 m sec. M wave appeared during the eye movements and for a while after cessation of the eye movements and then disappeared gradually, while the initial spike complex (shown in Fig. 5) did not disappear, but only were diminishing its amplitude during the repetitive stimulation.

Muscle relaxant (Flaxedil 0.1 mg/kg) was injected intravenously to immobilize the extraocular muscles and change of M wave observed at the same point of the experiment shown in Fig. 5.

M wave was not seen as shown in Fig. 6, when extraocular muscles were immobilized.

Topical injection of succinylcholine to immobilize the extraocular muscles resulted in same effect. After appearance of M wave was observed (Fig. 7 A-1), optic nerve was cut off in both sides to observe the effect of retinal stimulus on M wave.

No effects were observed in appearance of M wave, after optic nerve were cut off (Fig. 7 A-2).

Both sides of ophthalmic nerve were cut off to observe the change of M wave, as a result of this procedure appearance of M wave was shortened at the onset and the peak at about 1.5 m sec. (Fig. 7 B-2) compared with M wave before cut off (B-1).

From the results of these experiments shown in Fig. 5, 6, 7, afferent connecnections between extraocular muscle and brain stem were strongly suggested in vestibular eye movements.

DISCUSSION

Remarkable difference was observed in oculomotor nucleus evoked potentials between single shock and repetitive stimulation of anterior ampullary nerve. With regard to evoked potentials by anterior ampullary nerve stimulation, it seems likely that first component reached oculomotor nucleus directly via vestibular nucleus, while the second component had more neuronal pathways than the first component.

From the result of experiment shown in Fig. 3 (lower traces of each column), it is concluded that the superior rectus branch originated mainly from contralateral oculomotor nucleus, whille the inferior oblique branch from ipsilateral oculomotor nucleus. This result was in agreement with Warwick's[17] histological investigation and Shimo-oku's[14] electrophysiological investigation. Moreover, it was ascertained that unilateral anterior ampullary nerve projected mainly to contralateral oculomotor nucleus (Fig. 4).

Remarkable negative wave was seen by repetitive stimulation, which was not obtained by single shock stimulation (Fig. 5).

M wave disappeared for a while after the cessation of the eye movements, but on the contrary initial spike complex did not disappear in these course, only diminished the amplitude of spike. It is probable that this spike complex maintains the eye deviating at steady state even after M wave disappeared.

M wave should be considered at any rate to be derived from eye movements, because the exsistence of vestibular eye movements was indispensable for appearance of M wave. In this present experiment muscle relaxants were used intravenously and topically to immobilize the extraocular muscles, and then M wave was not obtained. Some authors suggested the exsistence of eye muscle sensory endings. This result shown in Fig. 5, 6 strongly demonstrates the exsistence of afferent connections from extraocular muscles to brain stem. In these experiments the intervals between initial spike complex and M wave was approximately 4–5 m sec. It strongly suggests the exsistence of close afferent route between extraocular muscles and brain stem. From the result shown in Fig. 7 B 1-2, it seems likely that ophthalmic nerve was concerned with the afferent route partialy and played a adjusting role to other unknown afferent activity.

In conclusion results above mentioned were illustrated in Fig. 8.

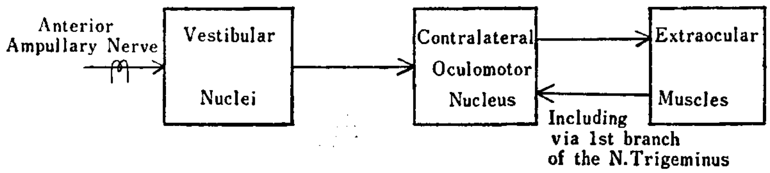


Fig. 8

SUMMARY

1. Using the anesthetized cats evoked potentials recorded in oculomotor nuclei in response to stimulation of the anterior ampullary nerve have been described.

2. Ipsilateral anterior ampullary nerve had close neuronal connections to the ipsilateral superior rectus branch and contralateral inferior branch of oculomotor nerve.

3. Contralateral oculomotor nucleus was more dominantly connected to anterior ampullary nerve rather than to ipsilateral oculomotor nucleus.

4. Remarkable negative wave (termed M wave) was recorded in contralateral oculomotor nucleus in about 7 m sec latency only by repetitive stimulation. This wave did not appear, when muscle relaxants were used to inhibit the eye movements. From the fact above described afferent connections between extraocular muscles and brainstem were concluded.

5. The 1st branch of N. trigeminus was concerned with the afferent route partially and played a adjusting role to other unknown afferent activity.

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Fig. 9 Microphotograph of midbrain. Electrode was remained in the point of shown in Fig. 4. B-5 at the depth of 7 mm from surface. Arrow indicates the electrode tip located in the posterior part of right oculomotor nucleus.