The Establishment of a Clinical Diagnostic Method of the Visual Evoked Potentials (VEPs) in the Cat: The Effects of Recording Electrode Positions, Stimulus Intensity and the Level of Anesthesia

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ABSTRACT. The establishment of characteristic wave pattern of visual evoked potentials (VEPs) in the cat was attempted in order to aid for clinical veterinary practitioners with the evaluation of visual dysfunction. 1) The position where the largest response of the VEPs was detected was close to the midline of the occipital area in normal cats. 2) The VEPs consisted of three components with latencies within 100 msec after flash stimulus. 3) Flash stimuli of higher illumination produced VEPs of shorter latencies and increased amplitude. Intensity of more than 0.6 J was necessary to obtain stable VEP patterns. 4) The latencies of VEPs hardly changed with time course under pentobarbital anesthesia, although they showed a fluctuant variation. —KEY WORDS: cat, electrode position, flash intensity, pentobarbital, visual evoked potential.

Clinical methods for evaluating a visual system in animals have been limited. In veterinary medicine, function of the visual system is examined by a menace response, a pupillary response to retinal light stimulation, and observing the animal walk on obstacles. These methods are not objective and need sometimes cooperation of the patient animals. Some kinds of evoked potentials, however, have been recently reported in humans and animals to evaluate different sensory systems for clinical application [1, 6, 9, 10, 12].

The visual evoked potentials (VEPs), also called the visually evoked responses or the visual evoked cortical potentials can be used in the objective assessment of visual disorders. They are gross electrical signals generated by the occipital region of the cortex in response to visual stimulation [4]. VEPs, the recording of which has recently been made possible by the development of computer averaging techniques, are useful for the evaluation of levels of anaesthesia, the study of brain function and the clinical diagnosis of neurological disorders in man [1, 16]. This technique is expected to used also in veterinary research, but there is few reports in this field.

Concerning cats, some experiments in this field have been reported by Doty, Saxton, and Torres and others [2, 3, 5, 14, 18]. But in these reports, the cat was used as a model for basic study of human medicine. For example, Saxton investigated whether the reference electrode put in a frontal sinus is competent in VEP recording [14]. Their findings were to suggest possible methods in application of VEPs in veterinary clinical medicine, but techniques of VEP recording had been investigated only in the dog [8] and the sheep [7]. However, we had nothing which can safely be called a typical pattern of VEP, because of the parameters that influence the wave pattern of the VEP [3, 11, 16].

In this paper, an attempt has been made to establish the way of detecting VEPs and
their characteristic wave patterns in cats in order to aid the diagnosis of visual dysfunction.

MATERIALS AND METHODS

Fifteen normal adult mongrel cats of both sexes were used. Their weights ranged from 2.0 to 4.2 kg. They were examined by the ophthalmoscope before experiment and no abnormal findings was revealed on their tapetum lucidum, retina and optic disc, and their visual (photopic) ability seemed normal, as judged by the observation of their behavior. The cats were anesthetized with an intravenous injection of sodium pentobarbital at the dose level of 10 mg/kg of body weight following subcutaneous administration of atropine sulfate and xylazine as pre-anesthetic drugs at the level of 0.05 and 2 mg/kg, respectively. The experiments were performed in a soundproof and darkened room which was electrically shielded and had a controlled room temperature ranged from 25 to 27°C. Body temperature was monitored during the experiment. A drop of tropicamide and phenylephrine hydrochloride (Midorine P: Santen Seiyaku) was instilled into each eye.

The electrodes were put under the scalp using a 26 gauge hypodermic needle. They were enamel-covered copper wires of 120 μm in diameter, and insulated enamel portions 1 mm in length at their tips were bared by concentrated sulphuric acid and bent back sharply against the needle shafts of 0.5 cm long [15]. The 26 gauge needles were removed after the electrodes were put under the skin. For the investigation of the appropriate recording position, recording electrodes were put in 9 positions as shown in Fig. 1, with a reference electrode at the contralateral ear and a ground electrode on the rhinal bone [16].

Electrocortical responses were evoked using a flash stimulator (Photic stimulator for retinograph, Nihon Kohden SLS-4100). A series of light flashes with constant intensity was applied on both eyes at intervals of 1 sec. The signal was fed back to a digital averager (NEC San-ei signal processor 7T17) after preamplification (system gain: 50,000) between 1.5 Hz and 3 KHz, and was averaged 50 times followed by analysis. The averaged output was displayed simultaneously on an oscilloscope (Nihon Kohden VC-10). The analysis epoch was 102.4 msec (1024 points). To approve that the response was elicited from the light stimuli, the recording with cutting off flash stimuli was attempted firstly.

Changes of VEPs patterns to the luminous power were investigated. The intensities of flash illumination used were 0.3, 0.6 and 2 J; and to obtain a further weak stimulus, the light source under the intensity of 0.3 J was presented at a twice longer distance than the usual one. The usual distance between the photostimulator lamp and eyes was 20 cm.

To investigate the changes of VEPs patterns with time course under sodium pentobarbital anaesthesia, VEP was recorded at every 10 minutes after 10 minutes from the administration of sodium pentobarbital until the VEPs could not be detected because the level of the anesthesia became light and the cats moved.

RESULTS

Fig. 2 shows typical VEPs in a cat at No.6 recording position illustrated by Fig. 1. On this trial, the stimuli given were at the most intensive level. The VEPs consisted of three components with latencies within 100 msec after flash stimulus. The waves were termed as P1, N1, and P2 according to Creel et al. [3, 14, 16]. The amplitude was determined from P1 peak to N1 peak.

The latencies and amplitudes of VEPs in three cats are shown in Table 1. Although
there was no difference in latencies among recording positions, there were some differences in amplitude: greater response occurred as the recording positions get close to the vertex and the greatest was detected at No. 6 position. Therefore, in the following experiments, the VEPs were recorded at No. 6 position in Fig. 1.

When the change of VEP patterns was investigated by the alteration of the lumi-
nous power in four cats, it was demonstrated that the lower the flash stimulus was, the longer the latencies were (Fig. 3). This was particularly remarkable in P2. In addition, standard deviations of P2 values were larger than those of others. So P2 was more changeable than P1 and N1 among individual cats. A similar phenomenon was recognized in amplitude. In amplitude as well as in latencies, the response reached a plateau at intensities more than 0.6 J (Fig. 3-B). This suggested the stimulus got saturated at 0.6 J (discussed below). Thus, the following experiment was performed employing the highest level of the stimulus (2 J).

The change with time course under sodium pentobarbital anaesthesia is shown

![Graphs showing changes in amplitude and peak latency over time](image)

Fig. 3. (A) The effect of flash intensity on the latencies and amplitude of the VEPs in four cats. 0.3^* J means that the intensity of flash used was 0.3 J and the distance between the stimulator and the eyes was twofold. (B) The differences of the latencies and amplitude by the effect of flash intensity. Base lines indicate the value of recording stimulated at 2 J. The meaning of 0.3^* J is same as explained in (A).

![Graphs showing changes in peak latency over time](image)

Fig. 4. Changes with time course on the mean values and standard deviations of the latencies and amplitude of the cats' VEPs under pentobarbital anaesthesia. VEPs of eight cats were recorded until 60 min. However, two cats' VEPs could not be recorded after 70 min. and only the recordings for four cats could be completed by 80 min.
in Fig. 4. Although the latency of P1 was stable and that of N1 slightly decreased with time course, the latency of P2 varied greatly every time of recording and no general pattern was recognized. Similarly, the amplitude hardly changed and variations in individuals were great.

DISCUSSION

In this investigation on the location of the VEP recording, the appropriate recording place where the greatest response was obtained was the paramidline vertex in the occipital area. This area is near to that for direct recording from brain surface under sodium pentobarbital anaesthesia reported by Doty [5]. This place may be anatomicly cortical visual striate of cat cortex [5]. The patterns of VEPs were reported by Ciganek in man [1], Howard et al. in the dog [8], Gregory et al. in the sheep [7], and Creel et al. in the cat [2, 3]. Those waves were characterized by the positive-negative-positive triphasic waves. Creel et al. reported that the normal VEPs pattern was P15-N25-P35-N45 complex [2]. The latencies of each component were, however, different from those observed in our experiment. The cause of this difference might be the difference of the place of the reference electrode. Saxton et al. postulated that the reference electrode which was put on the frontal sinus introduced the potential of electroretinogram (ERG) [14]. So, it is suspected that the VEPs pattern by Creel et al. was superimposed by ERG. In some previous studies including those by Creel, the reference electrode was adopted at frontal sinus. Using a flash light as a visual stimulus, however, the potential recorded at frontal sinus comes from a volume conducted ERG and therefore VEP is modified by ERG. In the present study, the reference electrode was settled on contralateral ear since the reference had a less influence on the potential of volume conducted ERG.

Howard and Breazile reported the normal VEP in the dog [8] when the reference electrode was set on the supra optic process. It was only P2 that they detected, as is suspected from our result. Perhaps the difference of the position of the reference electrode, the gain of a preamplifier and the animal species caused the discrepancy: in our preliminary experiment, intensity of the flash stimulus was not always got stable in the dog because eye balls of dogs rotated so much downward under anaesthesia that their pupils could not directly receive the flash stimulation and bipolar (twopeak) wave of VEPs appeared if enough intensity of flash stimulus had been given during VEP recording.

There have been some reports on the effect of intensity of flash illumination on VEPs in humans, monkeys, rats, guinea pigs, and cats [3, 14, 16]. Those investigations gave consistent result that the latencies were shortened with the increase in the intensity of flash stimulus. Our result is also in agreement with this: the amplitudes of VEPs in the present study augmented as the intensity of flash stimulus increased. The difference of the latency and amplitude values between the intensity of 0.6 J and that of 2 J were both very small (Fig. 3-B). The variation appeared to be a in plateau state at the intensity of more than 0.6 J. This may give the reason the intensity of over 0.6 J of light flash would produce retinal saturation [3, 16].

There are few reports about the change of VEPs patterns under the sodium pentobarbital anaesthesia. As shown in the present paper, the latencies of each component of VEP were almost always constant, although they showed a fluctuant variation. Sutton et al. [17] reported that pentobarbital had no effect on the central somatosensory conduction time in the cat. The VEPs may not be influenced readily by anesthetic agents. It
appears that the effect of barbiturates is too small to be of clinical significance in the cat [17].

To explore the clinical application of VEP patterns in veterinary medicine, it is necessary to consider many parameters which may influence VEPs. Our result has shown that the intensity more than 0.6 J, which is considered to be the level of retinal saturation, is necessary to obtain a stable VEP. Under pentobarbital anaesthesia, the changes of the latencies of VEPs with time course may be minimum and therefore can be ignored.

REFERENCES

要約

猫の視覚誘発電位における刺激方法との関連について：宇塚雄次・土井章三・徳力幹彦1）・松本治庸（山口大学農学部家畜内科学教室、1）家畜生理学教室）——獣医学における視覚障害の客観的評価を行うための基準の一助として、猫において視覚誘発電位（VEP）の基本的波形の確立を試みた。1）VEPの記録部位について検討したところ、最も大きな反応が得られた部位は後頭部領域の傍正中であった。2）猫のVEPは瞬光刺激後100msec以内に3種の波成分（P1, N1, P2）がみられた。3）瞬光強度によるVEP波形の変化について検討したところ、瞬光強度の増加に伴い各成分の潜時は減少し、振幅は増大する傾向がみられたが、瞬光強度0.6Jにおいて飽和傾向が認められた。4）麻酔後の時間経過に伴うVEP波形の変動について調べたが、潜時はほとんど変化無く、振幅は個体間、個体内ともバラツキが大きく、特定の傾向はみられなかった。