Visual Evoked Potential from Scalp in Guinea Pigs

Minoru SUZUKI, Kiitiro SITIZYO, Takashi TAKEUCHI, and Toshiyuki SAITO[1)]

Department of Veterinary Physiology and [1)]Department of Veterinary Pharmacology, Faculty of Agriculture, Tottori University, Koyama-cho, Tottori 680, Japan

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ABSTRACT. Visual evoked potentials (VEPs) recorded from the scalp in guinea pigs were compared with those from the dura. The study was performed with ten adult male guinea pigs weighing 350–750 g. VEPs recorded from the scalp had large negative components (N_{40} and N_{75}) and a large positive component (P_{55}). The waveform of the VEP in the scalp recording was similar to that in the dural recording in that N_{40} was a major early negative component. Great differences between the scalp and the dural recording were observed in the late negative components (N_{75} and N_{140}). In the dural recording, the peak N_{75} was a very small component, and the peak N_{140} was very large. There was no significant difference between the peak latencies of the two kinds of VEPs except for the peaks P_{55} and P_{100}. Peak-to-peak amplitudes of VEPs recorded from the scalp were smaller than those from the dura except for P_{55}-N_{75}. The peak-to-peak amplitude in the scalp recording compared to that in the dural recording varied from a ratio as low as 1.0:2.9 to as high as 1.0:36.2, and was markedly variable in each component. The scalp recording correlated with the dural recording as regards the early component.—KEY WORDS: guinea pig, scalp electrode, VEP.

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Several studies concerning visual evoked potential (VEP) in guinea pigs have been reported by Campos and Welker [2], Creel *et al.* [4], Rosen and Remmes [8] and Sedláček [9]. These VEPs were recorded from implanted electrodes, because the VEP was often contaminated with eye movement artifacts and/or electromyogram. We have previously investigated the VEP concerning the conditions of photic stimulation by using implanted electrodes in guinea pigs [10]. For the purpose of clinical application, it is desirable that the technique be simple and the patients not damaged by measurement. In the scalp recording VEP by the use of needle electrodes has the merits of causing little damage to patients and requiring only a short time for the examinantion.

In human beings, one study concerning the change of VEP waves caused by the spread of cortical activity to the scalp has been reported [3]. However, there are few studies concerning the difference of scalp and dural recordings in veterinary science.

We therefore decided to investigate the difference of the VEPs from scalp and dural electrodes in guinea pigs.

MATERIALS AND METHODS

The study was performed with ten adult male guinea pigs weighing 350–750 g. The exploring electrodes consisted of two electrodes over the left and right occipital areas (LO, RO), and a reference electrode (N) located just behind the tip of the nose. The electrode placements conformed to the method reported by Creel *et al.* [4]. The electrodes to the occipital areas were placed bilaterally 2 mm anterior to the lambdoidal point and 5 mm lateral to the sagittal suture. The reference electrode was on the midline and was 12 mm anterior to bregma (Fig. 1).

The VEPs from the scalp were recorded from subcutaneously placed stainless-steel needle electrodes in five animals. It was necessary to infiltrate the skin and subcutaneous tissue at the point of application of the electrode with a local anesthesia of 1 per cent lidocaine hydrochloride. Then, the electrodes were inserted into the subcutaneous tissue and fixed with an adhesive.

The VEPs from the dura were recorded from implanted silver-ball electrodes in the other five animals, using clean surgical techniques. The animals were given a general anesthetic of pentobarbital sodium (25 mg/kg body weight, ip). Holes of 1 mm in diameter were then drilled through the skull and the electrodes were firmly fixed at the dura with dental cement. The reference electrode was fixed at the skull in the same way. One week after electrode implantation, the VEPs were recorded.

The experiments were performed in an electrically-shielded room. The animals were restrained using a restraint box, leaving the head exposed. After dark-adaptation for 30 minutes, brief flashes from a

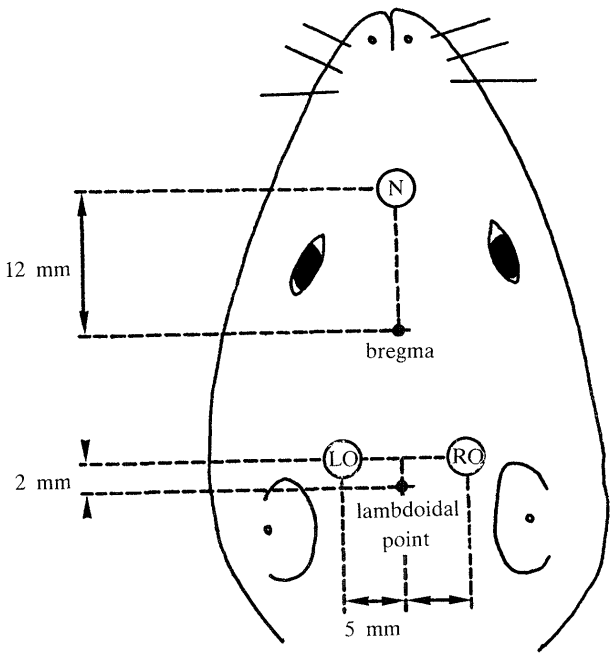

Fig. 1. Electrode placements in guinea pigs.
The electrodes to the occipital areas were placed bilaterally 2 mm anterior to the lambdoidal point and 5 mm lateral to the sagittal suture. The reference electrode was on the midline and was 12 mm anterior to bregma.

STROBOSCOPE photostimulator placed 20 cm away from the eyes were presented to both eyes for 5 minutes with a frequency of 0.5 counts per second. The luminous intensity of the flash was approximately 80 lux at a distance of 20 cm from the photostimulator. The click sounds of the photostimulator generated by the discharge were not removed. The intensity level of the click sound was sufficient to be audible to the human ear.

All recording sessions were carried out on awake animals. The VEPs were recorded on a polygraph (Model 1A52, San-ei Sokki Co., Ltd.) and simultaneously on a magnetic tape recorder (Model FRC-1402N, SONY) with the following instrument settings: amplification sensitivity, 50 μV/5 mm (scalp recording), and 100 μV/5 mm or 200 μV/5 mm (dural recording): time constant, 0.3 second: high cut filter, 60 Hz.

The evoked responses which had been stored on tape were averaged with a computer (signal processor 7T08, San-ei Sokki Co., Ltd.), using a 512 msec sweep duration. The averages of the responses were made from 140 samles, and were reproduced on an X-Y recorder (Model 8U11, San-ei Sokki Co., Ltd.). Negativity at the exploring electrode on the occipital areas of the animals resulted in upward deflection on graphs.

RESULTS

A. VEP waves from scalp and dural electrodes: VEPs recorded from the scalp had four negative peaks N_{20}, N_{40}, N_{75}, N_{140}, and five positive peaks P_{10}, P_{30}, P_{55}, P_{100}, P_{200} with all peaks up to P_{200} having a latency of about 200 msec (Fig. 2). In accordance with the report by Creel *et al.* [4], it is considered that the peaks up to N_{40} were primary responses, and the other peaks were secondary responses. The peaks N_{40} and N_{75} were large negative components and P_{55} was a large positive component. The peaks N_{20} and P_{30} rarely appeared. This waveform of the VEP was similar to that in the dural recording with a large negative component (N_{40}). Great differences between the scalp and dural recordings were observed in the late negative components (N_{75} and N_{140}). That is, in the dural recording, the peak N_{75} was a very small component and the peak N_{140} was very large (Fig. 2).

B. Comparison of peak latencies between the VEPs from scalp and dura: The peak latencies of the VEP recorded from the scalp and the dura are shown in Table 1. There was no significant difference between the peak latencies of the two kinds of VEPs except for the peaks P_{55} and P_{100}. The peak latency of P_{55} was significantly ($P<0.01$) shorter, and the peak latency of P_{100} was significantly ($P<0.01$) longer than those in the dural recording.

C. Comparison of peak-to-peak amplitudes between the VEPs from scalp and dura: Amplitude measurements were made from peak to peak, and the results are shown in Table 2. The peaks N_{20} and P_{30} rarely appeared, so that the peak-to-peak amplitudes of these peaks were not obtained. The peak-to-peak amplitudes of the VEPs recorded from the scalp were smaller than those from the dura except for P_{55}-N_{75}. The ratio of the peak-to-peak amplitude of the scalp recording to the dural recording varied from as low as 1.0:2.9 to as high as 1.0:36.2 and was markedly variable in each component. In the peak-to-peak amplitude P_{100}-N_{140}, the ratio was highest. On the contrary, the peak-to-peak amplitude P_{55}-N_{75} in the scalp recording was slightly larger than that in the dural recording.

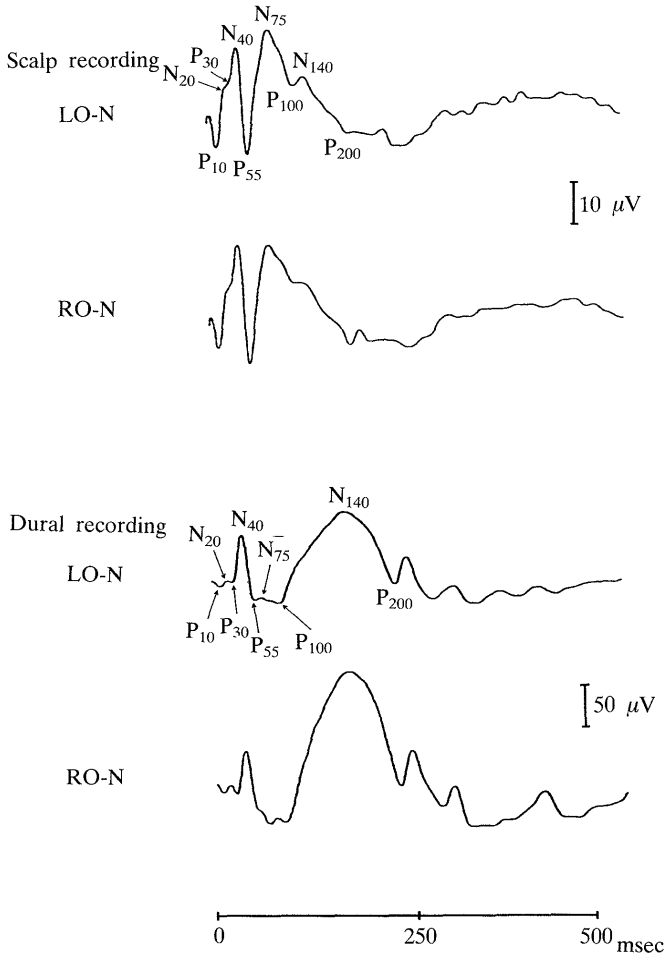

Fig. 2. VEP waveforms of guinea pigs from scalp and dural electrodes.

DISCUSSION

Creel *et al.* [4] reported that the VEP from chronically implanted electrodes in guinea pigs had eight peaks with latencies of 16.3 msec (negative, N), 23.3 msec (positive, P), 31.3 msec (N), 44.2 msec (P), 55.7 msec (N), 77.3 msec (P), 137.7 msec (N) and 201.5 msec (P), respectively. Rosen and Remmes [8] reported that the most identifiable early component of the VEP from dural electrodes was a positive wave with a peak at 50–55 msec in guinea pigs, while the most consistent late component was a negative wave with a peak at 150–175 msec. In the present study, the peak latencies in the dural recording were longer than those reported by Creel *et al.* [4], in the range of 10–20 msec. The peak latencies of N_{20} and P_{30} did not correspond to those of previous report [4]. These differences seem to have been caused by the experimental apparatus and procedure, such as luminous intensity, pupillary motility, illumination in the experimental room, and click sounds.

Comparing VEPs recorded from the scalp and dura, peak latencies in the scalp recording were slightly shorter than those in the dural recording except for N_{75} and P_{100}. This seems to be contradictory to the anatomical findings. Ichijo *et al.* [5, 6] studied the scalp topography of somatosensory evoked potentials (SEPs) in men, and stated that the phase of the wave delayed gradually with a decrement of the potentials (volume conduction). The postulate is that the reduction of latency is caused by this phase delay. The result that the peak latency in the scalp recording was shorter than that in the dural recording can therefore be explained in terms of phase delay.

In the present study, the VEP recorded from the scalp had large negative components (N_{40} and N_{75}),

Table 1. Peak latencies of VEP from scalp and dural recordings
(a) Scalp recording

Lead		Peak								
		P_{10}	N_{20}	P_{30}	N_{40}	P_{55}	N_{75}	P_{100}	N_{140}	P_{200}
LO-N	n	5	1	1	5	5	5	3	3	5
	Mean	14.2	—	—	38.8	54.4	74.6	109.0	130.7	201.5
	S.D.	1.6	—	—	1.9	2.5	2.6	6.0	9.8	19.1
RO-N	n	5	—	—	5	5	5	4	4	5
	Mean	13.6	—	—	38.2	53.0	73.8	111.0	134.5	203.2
	S.D.	0.5	—	—	1.5	2.0	2.0	7.5	9.9	19.3

(msec)

(b) Dural recording

Lead		Peak								
		P_{10}	N_{20}	P_{30}	N_{40}	P_{55}	N_{75}	P_{100}	N_{140}	P_{200}
LO-N	n	5	1	1	5	5	5	5	5	5
	Mean	16.6	—	—	42.8	59.6	67.8	88.8[a)]	153.6	218.8
	S.D.	4.5	—	—	3.1	3.5	3.9	7.8	11.9	10.7
RO-N	n	5	3	3	5	5	5	5	5	5
	Mean	15.8	28.6	35.0	44.0	62.2[a)]	70.4	88.2[a)]	158.6	217.0
	S.D.	5.0	9.7	8.5	4.8	2.7	3.7	10.5	13.9	10.7

a) Significant difference ($P<0.01$) from latency of scalp recording. (msec)

Table 2. Peak-to-peak amplitudes of VEP from scalp and dural recordings
(a) Scalp recording

Lead		Peak-to-Peak					
		P_{10}-N_{40}	N_{40}-P_{55}	P_{55}-N_{75}	N_{75}-P_{100}	P_{100}-N_{140}	N_{140}-P_{200}
LO-N	n	5	5	5	3	3	3
	Mean	14.9	12.1	13.0	5.2	2.5	12.7
	S.D.	5.7	5.3	4.0	1.0	1.7	2.5
RO-N	n	5	5	5	4	4	4
	Mean	15.3	13.6	12.7	7.1	2.3	10.6
	S.D.	4.0	4.9	5.4	3.5	0.9	1.7

(μV)

(b) Dural recording

Lead		Peak-to-Peak					
		P_{10}-N_{40}	N_{40}-P_{55}	P_{55}-N_{75}	N_{75}-P_{100}	P_{100}-N_{140}	N_{140}-P_{200}
LO-N	n	5	5	5	5	5	5
	Mean	74.7[a)]	77.2[a)]	11.3	23.4	85.8[a)]	64.8[a)]
	S.D.	36.0	15.8	7.9	12.3	29.3	23.4
RO-N	n	5	5	5	5	5	5
	Mean	69.6[a)]	65.1[a)]	6.9	20.4	83.4[a)]	60.9
	S.D.	23.9	12.6	8.5	13.4	36.3	29.2

a) Significant difference ($P<0.01$) from amplitude of scalp recording. (μV)

while the VEP from the dura had another large negative component (N_{140}) and the peak N_{75} was a very small component. Creel *et al.* [4] reported that the peak-to-peak amplitudes of the negative peak with latency of 31.3 msec, 55.7 msec and 137.7 msec were 124.8 μV, 90.5 μV and 162.8 μV, respectively. The peaks with latencies of 31.3 msec and 137.7 msec were very large negative components. The VEP recorded from the dura, in this experiment, was similar to that of the previous report [4] as regards these large negative components while the peak N_{75} was a very small component.

The peak-to-peak amplitudes of the VEPs recorded from the scalp were smaller than those from the dura. The decreased potential conducting from the cortex to the scalp was not the same proportion in each component. Cooper *et al.* [3] reported that comparison of the amplitude of signals from the scalp and the intracerebral electrode showed that there is an attenuation factor of about 40:1 of the spike component after the discharge, and also a small attenuation factor (3:1) of some of the alpha activity. Further they reported that the cortical responses to flashes included a positive deflection of about 200 μV, not found in scalp recordings in human beings. In the present study, a comparison of the peak-to-peak amplitude in the scalp and dural recordings showed that the ratio of scalp to cortex, in the early component (P_{10}-N_{40}), varied from as low as 1.0:4.5 to as high as 1.0:5.0, while in the later component (P_{100}-N_{140}), it varied from as low as 1.0:34.3 to as high as 1.0: 36.2. From the previous reports, it is considered that the degree of spread from the cortex to the scalp differed due to the attenuation factor, for example, a primary or a secondary response.

In this experiment, flashes and click sounds were presented simultaneously, so that auditory evoked potentials (AEPs) were mixed into the VEP. In general, AEPs were clearly recorded from the temporal area [7]. Brankatschk and Klingberg [1] reported that the response to the click sound was also observed in the visual area in rats. We formerly reported a study concerning responses to photic stimulation which removed click sounds [10, 11]. In the case of photic stimulation only, each peak of the VEP appeared more clearly. However, in a few cases stimulated by flash and click sounds, the VEP waveforms were multiform. It is therefore necessary to consider the influence of AEPs on VEPs.

The peak N_{20} and P_{30} rarely appeared in this experiment, so that it may be doubtful whether these peaks really originated in the VEP. However, we have previously reported that the peaks N_{20} and P_{30} appeared in a majority of cases stimulated only by flashes [10, 11]. This suggests that these peaks are part of the early components of the VEP.

In general, it is considered that the information obtained from the dural recording is more dependable than that from the scalp recording. In the present study, the waveform of the VEP in the scalp recording was similar to that in the dural recording in that N_{40} was a major early negative component.

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