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Clinical Relevance of Mobile Phone Interference with Electroretinography in Healthy Dogs: Experimental Study

Sunjun Jung, Dongbin Lee, Jury Kim, Minsu Kim*, Suyoung Heo and Namsoo Kim[1]

College of Veterinary Medicine, Jeonbuk National University, Iksan 54596, Korea
**College of Veterinary Medicine, Seoul National University, Seoul 08826, Korea*

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Abstract : This study aimed to confirm the effects that the mobile phone has on Electroretinogram (ERG). The ERG responses of three groups of healthy dogs, five in each group, were studied. ERG test was performed consecutively before and after the mobile phone was carried out. For group A, music was played with the sound on; for group B, music was played but the sound off; and for group C, the phone was set on the airplane mode. In the presence of a mobile phone, the amplitudes of a- and b-wave were increased in all groups. The a- and b-wave amplitudes at the flash intensity of 3,000 mcd·s/m^2 were significantly increased in all groups ($p < 0.05$). Based on the results, it is recommended to conduct ERG test in the absence of a mobile phone for the accurate evaluation of the retinal function.

***Key words* :** ERG, mobile phone, a-wave, b-wave, dog.

Introduction

Nowadays, many people have become inseparable from mobile phones and the rate of mobile phone possession is increasing steadily. However, because of the interference caused by mobile phones, their use is prohibited in some places. On an airplane, for example, it is required to turn off mobile phones because their radiofrequency signals can interfere with the plane's navigation system (1,19). Furthermore, because of the risk of interference with certain electromedical devices, the use of mobile phones is restricted within a hospital (2,6).

The electrodiagnostic testing of vision facilitates the evaluation of the visual system, from the retina to the visual cortex, in virtually any animal species. The electroretinogram (ERG) represents one of these testing modalities and is the most widely used modality in veterinary ophthalmology for assessing outer retinal function (4,11). An ERG is a recording of a complex response of different cells within the retina and is often used to diagnose outer retinal disease. Among some different types of ERGs, the full-field flash ERG is the most commonly used, and it allows for the early diagnoses of retinal diseases and facilitates making decisions involved in performing cataract surgery (3,9).

During an ERG, the retina is illuminated by various durations of exposure to light with various wavelengths and intensities. Light stimulates the individual types of nerve cells in the retina, and the electrical charges induced by light are recorded as a waveform (9). Most commonly, a-waves and b-waves are measured to evaluate the retinal function (18). The a-wave, the first negative deflection of a wavelet, reflects the negative change in the intracellular charge of photoreceptor cells (24). The b-wave, the next positive peak, relates to bipolar cell activity (12,13). The interpretation of the generated ERGs requires the overall waveform and the measure of the amplitude and implicit time of each wavelet (3,20).

The results of the ERG test may be influenced by some factors. Physiological factors, such as the status of retinal light/dark adaptation, rotation of the globe, degree of mydriasis, presence of intraocular inflammation and anesthesia-related variations (e.g. anesthetic agents, depth of anesthesia), could affect the results of ERG recordings. The device-related factors that can interfere with an ERG include electromagnetic waves and electrostatic waves, which could be emitted from the other electronic devices present in the examination room. Also, the type and position of the electrodes used in the ERG test could affect the results. Other factors that could interfere with an ERG are noise, humidity, temperature, etc. (7,10,14,15,18).

The reports available so far may imply that having a mobile phone on person may be another factor affecting the ERG results. To the author's knowledge, there are no reports on how a mobile phone affects an ERG recording. The purpose of this study is to report on whether a mobile phone can significantly affect ERG values or not and if so, on how it affects the values of an ERG.

Materials and Methods

Animals

Fifteen castrated, male, beagle dogs, weighing 9-12 kg, that were about a year old were included in this study. All the animals fasted for a 12-hour period before the ERG tests were conducted. Dogs were only included if the general physical and ocular examinations, as well as the laboratory analyses, such as the complete blood cell counts and serum

[1]Corresponding author.
E-mail : namsoo@jbnu.ac.kr

biochemistry panels, were normal. Ocular examinations included intraocular pressure, Schirmer tear test, slit lamp examination and fundus examination using indirect ophthalmoscope. Neurological examinations including corneal reflex, menace response, dazzle reflex, palpebral reflex, and pupillary light reflex with red, blue and white light were normal for all the dogs. The dogs were divided into three groups of five each. Both the right and left eyes were regarded as individual objects, so ERGs were performed on ten eyes in each group.

The present study was performed in accordance with the rules of the Ethics Committee for Experimental Animals, the Jeonbuk National University.

Devices

Electroretinography (ERG)

The ERGs were obtained using the Handheld Multispecies ERG (HMsERG) Model 2000 (RetVet; Columbia, MO, USA). The ERG protocol utilized in this study was the *short protocol*, and two flash intensities, 3,000 and 10,000 mcd s/m^2, were used. A contact lens monopolar electrode, ERG-Jet (Fabrinal; La Chaux-de-Fonds, Switzerland) was used as the active electrode. Stainless steel subdermal needle electrodes, F-E2 (OcuScience; Henderson, USA) were used as the reference and ground electrodes. Impedance and baseline tests were performed prior to the ERG test for each recording.

Mobile phone

Model Galaxy S7 (Samsung; Suwon, South Korea) was used for the study.

Experiments

Grouping

A different mode of the mobile phone was employed for each of the groups; for group A, music was played with the sound on; for group B, music was played but the sound off; and for group C, the mobile phone was set on an airplane mode.

Three different modes were set up to simulate different states of the mobile phone. 'Music on / sound on' mode was to activate the mobile phone and to add the acoustic effect while 'Music on / sound off' mode was to activate the mobile phone but to exclude the acoustic effect. 'Airplane mode' was to block the transmission signal of the mobile phone.

The volume level of the music in group A was set at 68 dB on an average.

Procedure

The ERGs were performed in a soundproof room without any other electrical or electronic devices in order to exclude interferences and to focus on the effects of the mobile phone. The test was conducted in full darkness condition with the red flashlight turned on.

Before the test, 1% tropicamide (Mydrin-P; Santen) was applied to both eyes, followed by 20 minutes of dark adaptation. Following this, medetomidine (0.3 mg/kg, IM) (Tomidin; Provet) was administered. The respiration and heart function were monitored via auscultation throughout the ERG test. After sedation, each dog was positioned in sternal recumbency. Following the induction of corneal anesthesia with proparacaine hydrochloride 0.5% (Alcaine; Alcon), the electrodes were placed. Ultrasound gel was used to maintain the active electrode on the cornea. The reference electrode was placed subcutaneously at 5cm aboral to the lateral cantus. The ground electrode was placed subcutaneously at the top portion of the skull. After the placing of the electrodes, the *short protocol* of ERG was performed on the right eye. The left eye was examined in the same way after the examination of the right eye was completed. ERGs were then repeated via the same protocol after introducing a mobile phone into the room. Because the door was opened to bring the mobile phone into the room, a second 20-minute dark adaptation was performed before the ERG test. Mobile phone was set upside down to eliminate the effects of the mobile phone lights. In order to maximize the influence of the mobile phone, the distance between the ERG device and the mobile phone was set to 10 cm.

Statistical analysis

The a- and b-wave amplitudes and implicit time parameters were evaluated for the determination of the effect that the mobile phone had on the ERGs. Normal distribution of data was examined using Kolmogorov-Smirnov and Shapiro-Wilk tests and consequently paired t-test and Wilcoxon signed rank test were used to compare each ERG parameters between with and without the mobile phone. For comparing the effect of the different modes of mobile phone between 3 groups, the difference ratio between before and after introducing the mobile phone in each group was calculated and one-way ANOVA was used following the normality test of each variable. The Bonferroni post hoc test was applied to isolate significance among groups. P values less than 0.05 were considered statistically significant and all statistical analyses were performed by using SPSS Statistics for Windows (version 18.0, IBM Armonk, NY).

Results

ERG variables of each group were evaluated to compare the effect of the mobile phone and shown in Table 1-3. In all groups, the amplitudes of a- and b-wave at two flash intensities were increased in the presence of the mobile phone. Especially, a- and b-wave amplitudes at the flash intensity of 3,000 mcd·s/m^2 were significantly increased in all groups ($p < 0.05$) (Fig 1). Also, the a-wave amplitude at the flash intensity of 10,000 mcd·s/m^2 in group A and b-wave amplitude at the flash intensity of 10,000 mcd·s/m^2 in group C were increased significantly ($p < 0.05$).

The differences in ERG values before and after introducing mobile phones between the groups were not significantly different.

Discussion

It is well known that electronic devices affect ERG recordings (11,18). Therefore, ERG should be conducted in an environment with a complete blockage of electrical interference. This study aimed to report on whether a mobile phone can

Table 1. ERG values in Group A (music-on/sound-on)

			Pre	Post (with mobile phone)
Flash intensity	3,000 (mcd·s/m^2)	Amplitude (μV)		
		• a-wave**	42.92 ± 21.37	79.87 ± 33.31
		• b-wave*	194.77 ± 41.65	237.93 ± 49.82
		Implicit time (ms)		
		• a-wave	15.32 ± 1.06	14.87 ± 0.96
		• b-wave	37.46 ± 6.13	33.72 ± 3.87
	10,000 (mcd·s/m^2)	Amplitude (μV)		
		• a-wave*	78.01 ± 33.62	105.96 ± 47.83
		• b-wave	220.73 ± 56.41	247.14 ± 68.44
		Implicit time (ms)		
		• a-wave	14.67 ± 1.82	14.59 ± 2.12
		• b-wave	36.82 ± 5.75	35.36 ± 4.10

Data is reported as mean ± standard deviation.
*P < 0.05; **P < 0.01.

Table 2. ERG values in Group B (music-on/sound-off)

			Pre	Post (with mobile phone)
Flash intensity	3,000 (mcd·s/m^2)	Amplitude (μV)		
		• a-wave*	58.18 ± 11.54	81.38 ± 22.66
		• b-wave*	236.40 ± 43.14	275.23 ± 62.83
		Implicit time (ms)		
		• a-wave	15.89 ± 1.91	17.01 ± 2.20
		• b-wave	45.79 ± 9.26	47.29 ± 8.01
	10,000 (mcd·s/m^2)	Amplitude (μV)		
		• a-wave	92.11 ± 27.21	110.37 ± 31.31
		• b-wave	278.55 ± 78.41	284.52 ± 71.08
		Implicit time (ms)		
		• a-wave	15.52 ± 2.80	16.73 ± 2.92
		• b-wave	47.34 ± 18.21	44.56 ± 7.14

Data is reported as mean ± standard deviation.
*P < 0.05; **P < 0.01.

Table 3. ERG values in Group C (airplane mode)

			Pre	Post (with mobile phone)
Flash intensity	3,000 (mcd·s/m^2)	Amplitude (μV)		
		• a-wave**	62.25 ± 23.38	97.47 ± 19.50
		• b-wave**	213.64 ± 61.63	267.16 ± 39.92
		Implicit time (ms)		
		• a-wave	15.96 ± 1.53	15.76 ± 2.10
		• b-wave	41.73 ± 7.86	37.77 ± 5.20
	10,000 (mcd·s/m^2)	Amplitude (μV)		
		• a-wave	103.35 ± 33.90	121.71 ± 28.80
		• b-wave*	240.16 ± 49.78	267.51 ± 41.42
		Implicit time (ms)		
		• a-wave	15.06 ± 3.44	15.92 ± 2.08
		• b-wave	39.40 ± 7.75	39.30 ± 4.17

Data is reported as mean ± standard deviation.
*P < 0.05; **P < 0.01.

significantly affect ERG values or not.

In this study, the a- and b-wave amplitudes were found to be increased in all groups in the presence of mobile phone during the ERG test. Although the modes of mobile phone

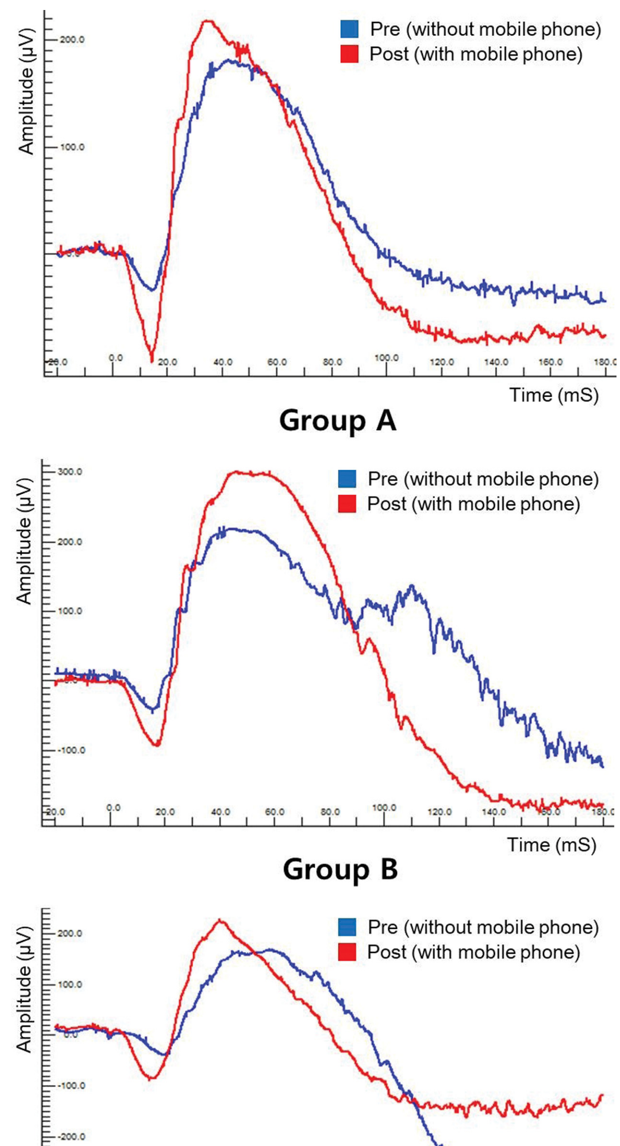

Fig 1. ERG at the flash intensity of 3,000 mcd·s/m^2. Note the a- and b-wave amplitudes are increased in the presence of mobile phone in all three groups.

used in the three groups were different, there was no significant difference between groups in the degree of influence. All three groups have different mobile phone modes, but the common factor that could affect ERG results was electromagnetic waves (EM waves).

Although the emission of EM waves is extremely reduced on the airplane mode, small amounts of EM waves still are emitted by the electrical components of the phone. There are several studies on the effect of EM waves on the retina, but still, the results are controversial. Some studies showed that EM waves have no significant effect on the retina (5,21), while others proved the damage of retina (8,16). Moreover, one study reported that EM waves significantly reduce the b-wave amplitude of ERG (23). In the present study, we found that the amplitude of the a-wave and b-wave increased when conducting ERG nearby the mobile phone. Assuming that the factor influenced the result of our study was EM waves, a possible hypothesis to explain this is the principle of superimposition of waves. Based on the principle, if an EM waves from the mobile phone and the electrical waves from the retina overlap at the same point, the resultant displacement (increase of the a- and b- wave amplitudes) could be measured by adding the displacements produced by each individual wave (17).

In this study, the distance between the ERG machine and mobile phone was set to 10 cm. Several studies have been conducted in order to investigate the distance from a mobile phone at which the exposure to the EM waves emitted by the phone can affect a user (6,22). According to a World Health Organization report, a user's exposure to EM waves decreases with increasing distance from a mobile device. It was reported that a person using a mobile phone 30-40 cm away from their body will have a low exposure to EM waves. If we assume that the EM waves generated from the mobile phone was the factor responsible for the results of this study, it may not have had a significant effect on the ERG values if the mobile phone was set further away from the ERG device. To confirm the influence that the EM waves generated from a mobile phone has on ERG recordings, further study with various distances between the mobile phone and the ERG device should be conducted.

There are several limitations to this study. Besides the small sample size, the differences in the depth of sedation over time could not be excluded. Considering the ERG test with a mobile phone was conducted later than the one without a mobile phone, the recovery from the sedation during the time period between the two tests could affect the results of this study.

Although it is unclear which factors of the mobile phone affected the ERG values, the results of our study support the fact that a mobile phone should not be taken when conducting the ERG test.

Conclusion

From this study, it was found that the mobile phone placed 10 cm from ERG device induces an increase in the amplitude of a- and b-waves of ERG. Consequently, the ERG test in the presence of the mobile phone can lead to misjudgment of the retinal function. Therefore, the mobile phone should not be carried during the ERG test.

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