Original Article

JVC Journal of Veterinary Clinics

pISSN 1598-298X • eISSN 2384-0749
J Vet Clin 2023;40:414-422
https://doi.org/10.17555/jvc.2023.40.6.414

Check for updates

A Comparative Study on Brainstem Auditory-Evoked Response between Dogs and Cats

Myeong-Yeon Lee
Sorin Choi
Dong-In Jung*

Institute of Animal Medicine, College of Veterinary Medicine, Gyeongsang National University, Jinju 52828, Korea

*Correspondence: jungdi@gnu.ac.kr

ORCID
Myeong-Yeon Lee:
https://orcid.org/0009-0009-1361-7388
Sorin Choi:
https://orcid.org/0009-0006-9527-6019
Dong-In Jung:
https://orcid.org/0000-0002-5116-6006

Abstract Hearing assessment is critical in dogs and cats. Hearing loss in dogs and cats may be congenital or secondary to a central nervous system disorder or ear disease. The brainstem auditory-evoked response (BAER) test has been developed as an electrophysiological test for auditory function assessment. Modern BAER equipment is based on a computerized system. Thus, auditory function assessment can be performed using this objective, safe, and noninvasive method. No study has yet investigated the interspecies differences between BAER test results of dogs and cats. Therefore, the present study aimed to analyze the differences in BAER test results between dogs and cats. The test was conducted on four healthy adult dogs and four healthy adult cats. Regarding latency, lower values were obtained for all waveforms above 50 dB in cats compared to dogs. Regarding amplitude, cats showed higher values than dogs at intensities above 50 dB. Through a comparative analysis in this study, it was concluded that the two species had statistically significant differences. The BAER data of dogs cannot be applied to cats, and vice versa.

Key words dog, cat, hearing assessment, brainstem auditory evoked response, insert earphone.

Received October 18, 2023 / Revised November 14, 2023 / Accepted November 20, 2023

Introduction

Auditory function is an invaluable method of perceiving the external environment. Animals may live without hearing, but deafness or hearing loss prevents the functions of a working and service dog, and communication with the owner or among conspecifics may also be impossible. Moreover, the affected animals are more vulnerable to danger, such as motor vehicles or predators (15,25).

Owners and breeders may desire a hearing assessment for certain reasons. Auditory function assessment in dogs and cats is crucial for the screening of breeds that have a risk of congenital deafness (18). Deafness in dogs and cats is mainly caused by genetic factors that are known to be associated with white pigmentation of skin and hair. In adult animals, conductive deafness may occur due to otitis externa, otitis media, and ear canal hypertrophy (23). Thus, an objective test of auditory function is necessary, as deafness may result from diverse causes.

In veterinary practice, the most basic test of auditory function is a behavioral assessment known as the Preyer reflex. This reflex is a method in which a sudden loud sound is produced, and then the pinna movement toward the direction of the sound or turning of the head is examined as a response. It is a method to detect only the presence or absence of auditory function, with the drawback that unilateral deafness or partial hearing loss cannot be assessed. Moreover, deaf animals may exhibit a Preyer reflex under the influence of visual cues, vibrations, and air movement, which poses a challenge for an accurate assessment of auditory abnormalities (29).

In contrast, the BAER test is an electrophysiological test that can objectively assess auditory function and hearing acuity. Repetitive acoustic stimuli are transferred to the cerebral cortex through the brainstem after passing through the cochlea to induce an electrical change. Such changes are called evoked responses or evoked potentials. The BAER test detects changes in such electrical signals, using electrodes applied to the scalp. The test is able to independently assess both ears, allowing assessment whether an animal is awake, sedated, or anesthetized. Modern BAER equipment is based on a computerized system, making it easy to operate, safe, and noninvasive. Another advantage is that objective and anatomically specific results are produced within a short period. For these reasons, many veterinarians and researchers use the BAER test as an alternative to behavioral assessment for testing auditory function (29).

In small animals, seven waves can be obtained within 10 ms from the onset of acoustic stimuli. The first positive wave is detected within 1.0-1.5 ms, and subsequent waves form in intervals ≤1 ms. Each positive wave is given a Roman numeral and characterized based on latency and amplitude (18,29). Nevertheless, not all waves are observed at all times; wave VII is generally not observed, and wave IV appears as waves III or V as if merged with them due to its small amplitude. Only the first five waves are clinically relevant. Each wave is known to appear at a specific anatomical location: wave I at the distal portion of cranial nerve VIII, wave II at the proximal portion of cranial nerve VIII, wave III at the cochlear nuclei after cranial

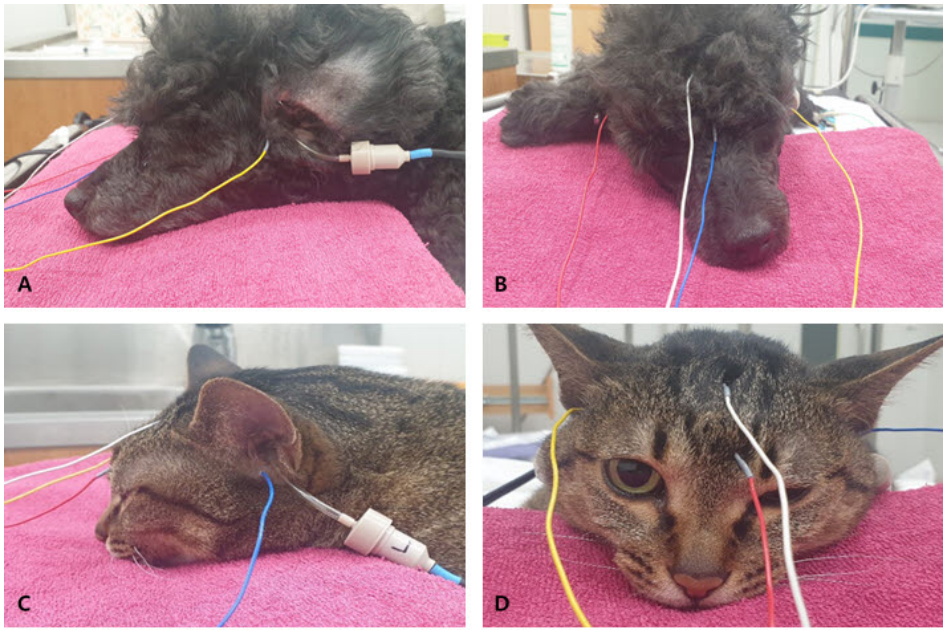

Fig. 1. Examples of animal position and location of needle electrodes in dogs (A, B) and cats (C, D).

nerve VIII, and wave V at multiple generator sites, including the inferior colliculus and medial geniculate body (18,29).

Thus, the BAER test serves as a tool that enables objective assessment of auditory function. For humans and dogs, various comparative studies have been conducted based on head size, sex, age, and body temperature (4,27,29). Dogs and cats account for the highest proportion of companion animals worldwide, and naturally, owners request a hearing assessment for various reasons (6,18). Since the development of the BAER test, it has been proactively conducted for 40 years (7). However, there are insufficient studies on the BAER test in cats (5,11,24,26). Thus, this study was conducted to investigate the possibility of applying BAER data of dogs to cats for a clinically valid assessment.

Materials and Methods

Subjects

This study was performed on clinically healthy client-owned dogs and cats. Four dogs and four cats were examined. In the dogs, three were female, and one was male, aged 1-5 years, weighing 5-10.8 kg. All cats were female, aged between 3-5 years, weighing 3.6-8.65 kg. Two dogs were poodles, one was a mixed breed, and one was a Cocker Spaniel, while all cats were Korean domestic shorthairs. Before the study, all dogs and cats were given a fasting period of 12 hours. The BAER test was conducted on the following dogs and cats based on history; the subjects had neither used an ototoxic drug nor were using a topical agent. Based on the results of otoscopic examination, otic swab examination, blood analysis, and radiography, the subjects did not have underlying diseases and were healthy without structural abnormalities that may affect auditory function. Ethical approval for this study was obtained from the Institutional Animal Care and Use Committees of Gyeongsang National University (approval no. GNU-200316-E0010).

Experimental protocol

The BAER test was conducted using the auditory brainstem response program of the Neuropack M1, MEB-9200 electrodiagnostic system (Nihon Kohden, Tokyo, Japan). All tests were conducted according to the manufacturer's instructions. The main unit was connected to the electrode junction box, JB-902BK (Nihon Kohden; Tokyo, Japan), which was connected to four monopolar needle electrodes, NM-710T (Nihon Kohden; Tokyo, Japan), of 13 mm length and 0.25 mm diameter. The insert earphone YE-103J (Nihon Kohden; Tokyo, Japan) was used as a transducer.

The BAER test was conducted in the electrogram room at the Gyeongsang National University Animal Medical Center. Interference was minimized to maintain a quiet environment. In the test, the animal received an intravenous (IV) injection of 0.02 mg/kg of butorphanol tartrate (Butophan; Myungmoon Pharm, Seoul, Korea), followed by an intravenous injection of 0.01 mg/kg of medetomidine hydrochloride (Sedator; Dechra, Shrewsbury, UK) for sedation. The sedated animal was positioned in sternal recumbency, while the head was slightly elevated using a folded towel. The body temperature was maintained at 37-39°C using a heating pad, and vital signs were monitored using electrocardiography and pulse oximetry. The four electrodes were each fully inserted into the vertex, forehead, and subcutis just anterior

Table 1. Mean wave I, II, III, and V latencies of cats and dogs

	dB	Dog		Cat	
		M	SD	M	SD
Wave I	90**	1.079	0.045	1.007	0.018
	80***	1.111	0.057	1.019	0.014
	70**	1.158	0.069	1.055	0.013
	60*	1.230	0.080	1.116	0.018
	50**	1.333	0.128	1.188	0.018
	40**	1.603	0.119	1.378	0.111
	30	1.736	0.151	1.609	0.033
	20*	1.913	0.176	1.750	0.027
Wave II	90*	1.822	0.055	1.748	0.016
	80**	1.850	0.064	1.754	0.017
	70*	1.895	0.070	1.801	0.012
	60*	1.959	0.074	1.864	0.014
	50*	2.069	0.134	1.936	0.027
	40**	2.303	0.109	2.111	0.083
	30	2.478	0.126	2.349	0.034
	20**	2.668	0.123	2.476	0.044
Wave III	90**	2.586	0.103	2.431	0.017
	80**	2.606	0.112	2.446	0.013
	70*	2.613	0.085	2.505	0.036
	60**	2.669	0.102	2.524	0.032
	50*	2.708	0.110	2.589	0.045
	40	2.824	0.114	2.746	0.101
	30*	3.030	0.098	2.911	0.096
	20*	3.222	0.166	3.018	0.086
Wave V	90	3.328	0.089	3.254	0.050
	80**	3.383	0.102	3.228	0.040
	70**	3.453	0.089	3.285	0.042
	60**	3.541	0.100	3.374	0.059
	50*	3.639	0.158	3.469	0.074
	40	3.818	0.173	3.671	0.098
	30	3.953	0.205	3.860	0.070
	20*	4.175	0.162	4.013	0.091

dB, decibel; M, mean; SD, standard deviation.
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

to the tragus of each ear. The preparation of each electrode is shown in Fig. 1. Before each test, an impedance check was conducted to confirm that the electrodes were correctly inserted. The stimulus type was set as a 0.1-ms click. The intensity of each test was decreased by 10 dB intervals from 90 dB normal hearing level (dBnHL) to 20 dBnHL, at which point the measurements were obtained. To remove the crossover effect, white noise of intensity 40 dB lower than the intensity for the tested ear was applied to the non-tested ear. Each waveform was acquired at a mean of 200-500 click stimulations based on a sampling time of 0.1 ms. Artifactual data were automatically rejected. The electrical activity was amplified to the range of 100-2,000 Hz using the AC filter. Each test lasted for at least 15 min, and at the end of the test, the animal was administered an intramuscular (IM) injection of 0.05 mg/kg of atipamezole hydrochloride (Atipam; Dechra, Shrewsbury, UK) to reverse the medetomidine hydrochloride sedation. Latency and amplitude were manually marked after the test by the same examiner.

Table 2. Mean wave I-III, III-V, and I-V IPLs of cats and dogs

	dB	Dog		Cat	
		M	SD	M	SD
Wave I-III IPL	90**	1.508	0.074	1.424	0.009
	80	1.495	0.082	1.428	0.010
	70	1.455	0.048	1.474	0.108
	60	1.439	0.058	1.408	0.028
	50	1.375	0.038	1.401	0.042
	40*	1.296	0.288	1.369	0.082
	30	1.294	0.114	1.298	0.094
	20	1.310	0.087	1.268	0.079
Wave III-V IPL	90*	0.741	0.094	0.823	0.041
	80	0.776	0.087	0.781	0.034
	70	0.841	0.074	0.790	0.037
	60	0.873	0.110	0.850	0.059
	50	0.931	0.079	0.880	0.052
	40	0.994	0.148	0.925	0.050
	30	0.923	0.213	0.949	0.061
	20	0.953	0.213	0.995	0.074
Wave III-V IPL	90	2.249	0.064	2.246	0.038
	80	2.271	0.064	2.209	0.032
	70*	2.296	0.053	2.230	0.040
	60	2.311	0.057	2.259	0.053
	50	2.306	0.086	2.282	0.064
	40	2.215	0.231	2.294	0.049
	30	2.216	0.312	2.251	0.060
	20	2.263	0.254	2.263	0.070

dB, decibel; IPL, interpeak latency; M, mean; SD, standard deviation.
**p < 0.01, *p < 0.05.

Statistics

Statistical analysis of the results was performed using the SPSS 25 software (IBM Corp., Armonk, NY, USA), using the Mann–Whitney test, with a significance threshold of $p < 0.05$.

Results

The BAER test and associated sedation were uneventful in all dogs and cats. In all animals, similar forms and shapes were observed across all intensities from 20-90 dBnHL, while replicable waveforms were detected. In all animals, wave VI was not detected. The mean and standard deviation of the latency

Table 3. Mean wave I, II, III, and V amplitudes of cats and dogs

	dB	Dog		Cat	
		M	SD	M	SD
Wave I	90***	3.272	0.734	6.258	0.929
	80***	3.141	0.672	6.120	0.969
	70***	2.688	0.676	5.536	1.026
	60**	1.705	0.735	3.725	0.946
	50***	0.683	0.320	1.983	0.610
	40	0.368	0.358	0.565	0.229
	30*	0.319	0.204	0.586	0.161
	20**	0.143	0.081	0.368	0.113
Wave II	90**	3.615	0.666	5.266	1.280
	80***	3.483	0.688	6.405	0.982
	70***	2.881	0.847	5.600	1.458
	60**	1.999	0.703	3.665	1.102
	50**	1.064	0.443	2.429	0.869
	40	0.692	0.356	0.912	0.397
	30	0.635	0.259	0.717	0.282
	20	0.400	0.121	0.406	0.162
Wave III	90***	1.850	0.819	6.329	1.238
	80***	1.727	0.766	5.183	1.051
	70***	1.462	0.768	4.415	1.119
	60***	1.271	0.557	2.909	0.766
	50***	0.933	0.384	2.172	0.577
	40*	0.556	0.376	1.069	0.362
	30*	0.495	0.312	0.822	0.199
	20	0.387	0.226	0.536	0.164
Wave V	90***	2.695	0.627	6.276	0.690
	80***	2.742	0.518	4.942	0.776
	70***	2.623	0.409	4.332	0.497
	60**	2.279	0.354	3.079	0.507
	50	1.906	0.488	2.240	0.364
	40	1.343	0.356	1.380	0.218
	30*	1.176	0.274	1.565	0.263
	20**	0.766	0.151	1.076	0.203

dB, decibel; M, mean; SD, standard deviation.
***p < 0.001, **p < 0.01, *p < 0.05.

of waves I, II, III, and V, and I-III interpeak latency (IPL), III-V IPL, and I-V IPL in Tables 1 and 2, respectively, and the amplitudes of waves I, II, III, and V in dogs and cats are presented in Table 3. The corresponding graphs are presented in Figs. 2-4.

The result of the comparison showed that the latency of wave I was shorter in cats than in dogs, with statistical significance except at 30 dB. The latency of wave II was shorter in cats than in dogs, with statistical significance except at 30 dB. The latency of wave III was shorter in cats than in dogs, with statistical significance except at 40 dB. Wave V latency was significantly shorter in cats than in dogs, with statistical significance except at 90 dB, 40 dB, and 30 dB. In all animals, the latency increased as the intensity decreased, but in all cats, the wave V latency was found to be shorter at 80 dB than at 90 dB.

IPL I-III showed statistically significant values only at 90 dB and 40 dB. At 90 dB, cats showed shorter latency than dogs, while at 40 dB, the reverse was observed. The III-V IPL showed statistically significant values only at 90 dB, and the latency was shorter in dogs than in cats. The I-V IPL showed statistically significant values only at 70 dB, and the latency was longer in dogs than in cats.

The amplitude of wave I was higher in cats than in dogs, with statistical significance except at 40 dB. The amplitude of wave II was higher in cats than in dogs, with statistical significance, except at intensities ≤40 dB. The amplitude of wave III was higher in cats than in dogs, with statistical significance except at 20 dB. The amplitude of wave V was higher in cats than in dogs, with statistical significance except at 40 dB and 50 dB. In all animals, the amplitude decreased as the intensity decreased, but in cats, the wave II amplitude was found to be higher at 80 dB and 70 dB than at 90 dB. After 80 dB, the amplitude decreased.

Discussion

BAER tests in humans have established normative data based on data collection (7). In dogs, such established normative data are still unavailable, although numerous studies have examined the auditory functions in dogs with respect to age, head size, sex, body temperature, and pharmacologic agents. However, in cats, very few BAER studies have been found (5,11,24,26). To our knowledge, this is the first study to perform a comparative analysis of dogs and cats. This study aimed to determine whether a clinically valid assessment is possible when the BAER data of dogs are applied to cats.

In this study, the BAER data of four dogs and four cats were obtained under identical conditions and compared. All dogs and cats examined in this study were provided various tests to exclude those who had a condition that might induce changes in the BAER test results. The electrical artifact was reduced using a transducer, and to prevent collapse in the external ear meatus, an insert earphone was used (29).

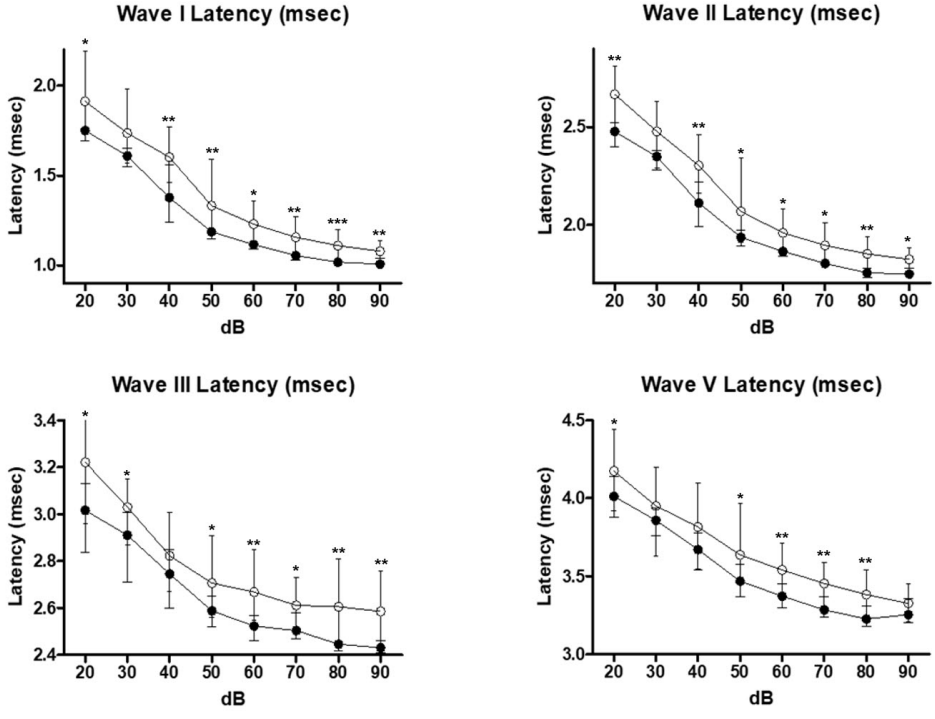

Fig. 2. Mean wave I, II, III, and V latencies of cats (●) and dogs (○). Error bars represent mean ± SD (***p < 0.001, **p < 0.01, *p < 0.05).

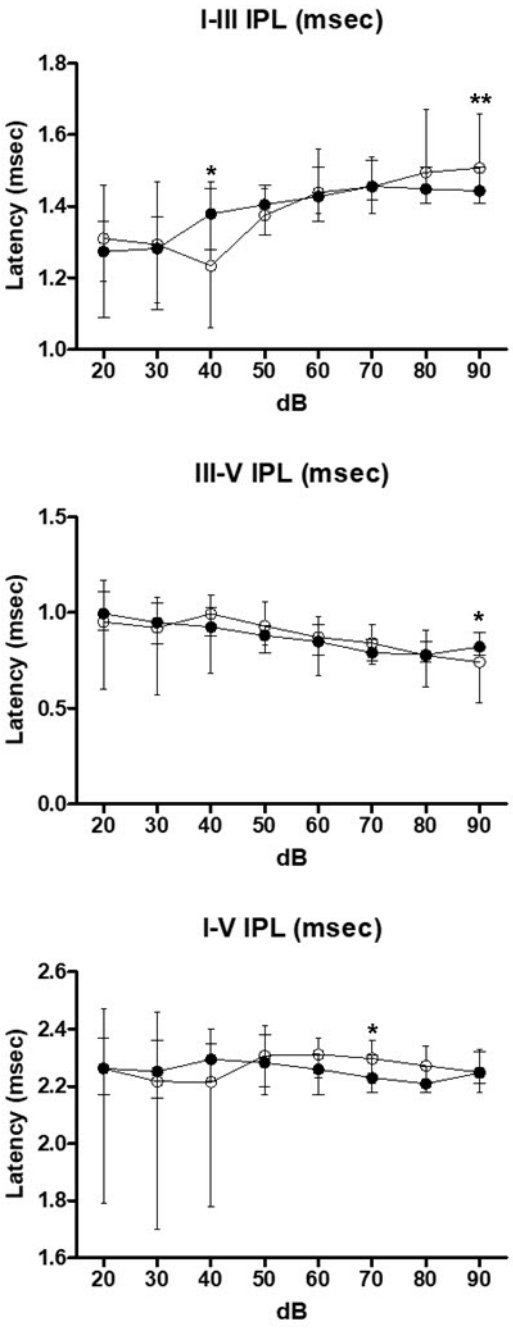

Fig. 3. Mean wave I–III, III–V, and I–V IPLs of cats (●) and dogs (○). Error bars represent mean ± SD (**$p < 0.01$, *$p < 0.05$).

As the BAER data are affected in aged cats and dogs, only the animals aged below or equal to 5 years underwent the BAER test (2,5). Generally, the BAER test is not influenced by sedation or anesthetization (8,12,20), and there are a number of studies that use medetomidine in the BAER test (1,11,14,22). Therefore, in this study, all animals were sedated using medetomidine. In one study, the latency was found to have increased at rectal temperature below 36°C, while no significant change are reported for temperatures of 37-39.5°C (2,29). Thus, a heating pad was used in this study to maintain the body temperature of all animals at 37-39°C.

The BAER test was used to assess the wave morphology, waveform repeatability, absolute wave latencies, absolute wave amplitudes, interwave latencies, wave V latency intensity (LI) functions, and hearing threshold. Wave morphology is subjectively assessed in terms of the overall shape and pattern of waves (16). Waves are labeled based on the repeatability produced at each intensity. Hence, it is possible to discriminate between a true peak and artifact by assessing repeatability of the waves produced. A lack of a repeatable waveform may result from hearing impairment or technical problems (16). Wave latency is the time taken for a positive or negative peak to appear in the wave (3,9). The wave amplitude is obtained through the positive peak of a given wave and the immediately following peak. Interwave latency is the latency between each peak, and generally, the latency is measured between waves I-III and between waves I-V (16). The Wave V LI function allows a graph to be drawn for the wave V latency based on each intensity for the assessment. By examining any changes in the shift or slope of this graph, hearing loss can be diagnosed (18).

The present study demonstrated that the BAER test results produced statistically significant differences between healthy dogs and cats. In both dogs and cats, four waveforms, waves I, II, III, and V, were observed, without the clinically relevant wave IV, and a repeatable waveform was found from 20-90 dBnHL. In line with previous studies, the wave morphology and structures were similar within the same species (18). However, differences were observed in wave morphology and structures between dogs and cats. The visual examination also detected markedly higher amplitudes in cats than in dogs. In addition, the trough immediately following wave V in dogs was substantially distant from the baseline, while that in cats was not so.

The BAER test is generally conducted at intensities ≥70 dBnHL such that the latency and IPL can be used for diagnostic purposes and to locate lesions. This is because the characteristics of wave morphology are more precise at intensities above or equal to 70 dBnHL, where the latency and IPL can also be more accurately determined (29). The IPL of waves I and III indicates the time taken for the electrical activity generated by BAER to reach the pons through the auditory nerve. The IPL of waves I and V are called the central conduction time, as they indicate the time taken for the generated action potential to reach the mesencephalon through the cochlear nerve (18). Thus, when a result with increased latency is obtained, the

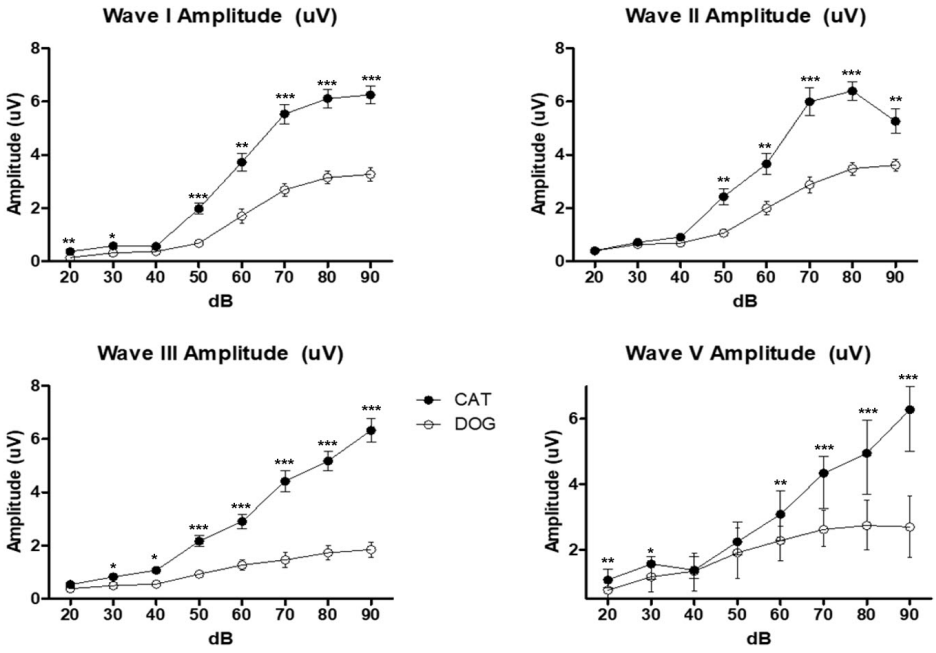

Fig. 4. Mean wave I, II, III, and V amplitudes of cats (●) and dogs (○). Error bars represent mean ± SD (***p < 0.001, **p < 0.01, *p < 0.05).

presence of a lesion may be conjectured at the site where the peak has been produced (24). For the latency at ≥70 dBnHL, all observed values were significantly shorter in cats than in dogs. In dogs, it is generally known that an increase in intensity leads to an increase in latency (20). Nevertheless, a surprising result was found for wave V latency in cats, where the latency was shorter at 80 dBnHL than at 90 dBnHL, only to increase again after 80 dBnHL. Although the cause is yet to be precisely determined, it is thought that this phenomenon should be considered in the interpretation of the BAER test results for cats. Considering the substantially small sample size in this study, further studies should be conducted.

The wave amplitude fell in the range of 1-6 μV. In the BAER test for dogs, waves I, II, and V showed high amplitudes, whereas wave III showed a low amplitude. Similar results were obtained for cats, although the amplitude has been reported to be lower in wave I than in wave II (18,19). However, in this study, wave II showed the highest amplitude in dogs, followed by waves I and V, while wave III showed the lowest amplitude. In contrast to previous studies, slight variations were observed for every intensity in cats. Wave amplitude may be influenced by nonpathologic factors, such as the materials and movements of the ear canal and asymmetrical electrode placements, and it is not always assessed because highly variable results are obtained in general (24,29). However, in both dogs and cats in this study, the observed amplitude was not highly variable. Nevertheless, further studies regarding the reference range are likely to allow auditory function assessment for dogs and cats based on the amplitude.

For the quantification of hearing level based on the BAER test, the most commonly used method is the visual examination of the lowest stimulus intensity exhibited by wave V (16,21). The assessment of the hearing threshold is most frequently reported for the BAER in dogs, and the threshold in adult dogs was shown to fall between 5-25 dBnHL (29). We did not include <20 dBnHL thus an accurate threshold could not be identified. Nevertheless, all waves were observed at 20 dBnHL in all animals, suggesting that the threshold in both dogs and cats may be <20 dBnHL.

The LI function is useful in assessing the nature of hearing impairment. A lateral shift along the intensity axis could be interpreted as arising from conductive hearing loss. A steeper curve than the reference range could indicate sensorineural hearing loss (17). Based on the results of this study, the latency was found to vary substantially between dogs and cats. Analyzing the wave V latency graph showed that when the normal range for cats is used to assess the LI function in dogs, a misdiagnosis of conductive hearing loss may result because one might presume a shift toward laterally. Therefore, in the mutual application of the BAER data, care should be taken as the interpretation may vary. Despite numerous studies on LI function in healthy dogs, this study presents the first normative data in cats. Thus, it is anticipated that the data of this study would prove to be useful in identifying the cause of hearing loss in cats. Three most common types of hereing loss in cats are hereditary congenital sensorineural

deafness (white pigmentation gene [W]), acquired late-onset conductive deafness (otitis externa/media) and acquired late-onset sensorineural deafness (otitis interna, drug toxicity, presbycusis environmental noise) (26).

Kemper et al. (7) conducted a study on BAER in dogs to examine the differences according to head size and breed. The study reported that, even when the head size and breed were different, the morphology, latency, and hearing sensitivity of BAER were similar in all dogs, suggesting that the differences in head size and breed exerted no influence on the use of BAER in dogs for the purpose of clinical diagnosis. Therefore, the differences in BAER waves in dogs and cats, as observed in this study, were presumed to be caused by multiple factors (ear canal, tympanic membrane, and nervous system differences) and not just by anatomical differences in head shape.

The effects of medetomidine are dose dependent, with the recommended dose range of 0.01-0.08 mg/kg in dogs and 0.05-0.15 mg/kg in cats (13,28). When using a dose higher than recommended, the duration of sedation increases while the intensity does not. A well-known side effect of medetomidine is vomiting, which is known to occur after injection in 20% of dogs and 90% of cats. Thus, vomiting is one of the main reasons why small animal practitioners refrain from using medetomidine for sedation of dogs and cats. An IV injection, rather than subcutaneous or intramuscular injection of medetomidine, reduces the probability of vomiting. The combined use of alpha-2 adrenoceptor agonists and opioids has been reported to show synergism (10). Therefore, in this study, the animals were administered an IV injection of 0.2 mg/kg butorphanol, followed by an IV injection of 0.01 mg/kg medetomidine, and the synergism from the combined use allowed reliable sedation without any side effect for the subsequent BAER test. Thus, the test could be conducted using a drug dose far lower than those in previous studies on BAER. This suggested that, using the same method in this study, the BAER test can be conducted without general anesthesia, by inducing reliable sedation free of side effects in cardiovascularly normal cats and dogs. Nonetheless, the risk of vomiting still exists; therefore, it would be safer to prevent vomiting using an antiemetic before the BAER test.

This study was conducted by recruiting only clinically healthy, client-owned dogs and cats. Despite a large body of studies regarding the BAER test in dogs, the reference range is yet to be established. This is due to the lack of consensus as the dogs vary in breed, and each study shows procedural differences. There is a general lack of studies on the BAER test in cats. Thus, the main limitations of this study were as follows: a considerably small number of animals were examined; a small number of previous studies on the BAER test in healthy animals are available; a unified protocol for conducting the BAER test is lacking; structural abnormalities did not assess through CT or MRI. If further studies are conducted to establish the reference range for dogs and cats, auditory function assessment will become more accurate. Our data are anticipated to prove useful in further studies on the BAER test for auditory function assessment in dogs and cats.

Conflicts of Interest

The authors have no conflicting interests.

References

1. Armașu M, Musteață M, Stanciu G, Mocanu D, Solcan G. Brainstem auditory evoked responses in healthy Argentine Mastiff dogs recorded with surface electrodes. Arq Bras Med Vet Zootec 2015; 67: 1457-1460.
2. Bodenhamer RD, Hunter JF, Luttgen PJ. Brain stem auditory-evoked responses in the dog. Am J Vet Res 1985; 46: 1787-1792.
3. Don M, Ponton CW, Eggermont JJ, Masuda A. Gender differences in cochlear response time: an explanation for gender amplitude differences in the unmasked auditory brain-stem response. J Acoust Soc Am 1993; 94: 2135-2148.
4. Durrant JD, Sabo DL, Hyre RJ. Gender, head size, and ABRs examined in large clinical sample. Ear Hear 1990; 11: 210-214.
5. Harrison J, Buchwald J. Auditory brainstem responses in the aged cat. Neurobiol Aging 1982; 3: 163-171.
6. Islam A, Towell T. Cat and dog companionship and well-being: a systematic review. Int J Appl Psychol 2013; 3: 149-155.
7. Kemper DL, Scheifele PM, Clark JG. Canine brainstem auditory evoked responses are not clinically impacted by head size or breed. Physiol Behav 2013; 110-111: 190-197.
8. Marshall AE. Brain stem auditory-evoked response of the nonanesthetized dog. Am J Vet Res 1985; 46: 966-973.
9. Munro KJ, Shiu JN, Cox CL. The effect of head size on the auditory brainstem response for two breeds of dog. Br J Audiol 1997; 31: 309-314.
10. Murrell JC. Pre-anaesthetic medication and sedation. In: Duke-Novakovski T, de Vries M, Seymour C, editors. BSAVA manual of canine and feline anaesthesia and analgesia. 3rd ed. Gloucester: BSAVA. 2016: 170-189.
11. Musteata M, Neculae I, Armasu M, Balan CB, Solcan G. Brainstem auditory evoked potentials in healthy cats recorded with surface electrodes. Acta Vet Brno 2013; 82: 97-101.
12. Myers LJ, Redding RW, Wilson S. Reference values of the brainstem auditory evoked response of methoxyflurane anesthetized and unanesthetized dogs. Vet Res Commun 1985; 9: 289-294.

13. Paddleford RR, Harvey RC. Alpha 2 agonists and antagonists. Vet Clin North Am Small Anim Pract 1999; 29: 737-745.
14. Plonek M, Nicpoń J, Kubiak K, Wrzosek M. A comparison of the brainstem auditory evoked response in healthy ears of unilaterally deaf dogs and bilaterally hearing dogs. Vet Res Commun 2017; 41: 23-31.
15. Ryugo DK, Menotti-Raymond M. Feline deafness. Vet Clin North Am Small Anim Pract 2012; 42: 1179-1207.
16. Scheifele PM, Clark JG. Electrodiagnostic evaluation of auditory function in the dog. Vet Clin North Am Small Anim Pract 2012; 42: 1241-1257.
17. Shiu JN, Munro KJ, Cox CL. Normative auditory brainstem response data for hearing threshold and neuro-otological diagnosis in the dog. J Small Anim Pract 1997; 38: 103-107.
18. Sims MH. Electrodiagnostic evaluation of auditory function. Vet Clin North Am Small Anim Pract 1988; 18: 913-944.
19. Sims MH, Horohov JE. Effects of xylazine and ketamine on the acoustic reflex and brain stem auditory-evoked response in the cat. Am J Vet Res 1986; 47: 102-109.
20. Sims MH, Moore RE. Auditory-evoked response in the clinically normal dog: early latency components. Am J Vet Res 1984; 45: 2019-2027.
21. Sininger YS. Auditory brain stem response for objective measures of hearing. Ear Hear 1993; 14: 23-30.
22. Stanciu GD, Musteață M, Armașu M, Solcan G. Evaluation of central vestibular syndrome in dogs using brainstem auditory evoked responses recorded with surface electrodes. Arq Bras Med Vet Zootec 2016; 68: 1422-1430.
23. Strain GM. Aetiology, prevalence and diagnosis of deafness in dogs and cats. Br Vet J 1996; 152: 17-36.
24. Strain GM. Brainstem auditory evoked response (BAER). In: Strain GM, editor. Deafness in dogs and cats. Cambridge: CABI. 2011: 83-107.
25. Strain GM. Canine deafness. Vet Clin North Am Small Anim Pract 2012; 42: 1209-1224.
26. Strain GM. Hearing disorders in cats: classification, pathology and diagnosis. J Feline Med Surg 2017; 19: 276-287.
27. Trune DR, Mitchell C, Phillips DS. The relative importance of head size, gender and age on the auditory brainstem response. Hear Res 1988; 32: 165-174.
28. Vainio O. Introduction to the clinical pharmacology of medetomidine. Acta Vet Scand Suppl 1989; 85: 85-88.
29. Wilson WJ, Mills PC. Brainstem auditory-evoked response in dogs. Am J Vet Res 2005; 66: 2177-2187.