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Canine brainstem auditory evoked responses are not clinically impacted by head size or breed

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HIGHLIGHTS

- Canine head size and breed effects examined on BAERs using standardized parameters.
- Head measurements and BAER tests performed on 43 dogs from fourteen breeds.
- Dogs had diagnostic results within expected ranges allowing clinical evaluation.
- BAER morphology, latency or hearing sensitivity not impacted by head size or breed.

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ABSTRACT

Accurate assessment of canine hearing is essential to decrease the incidence of hereditary deafness in predisposed breeds and to substantiate hearing acuity. The Brainstem Auditory Evoked Response (BAER) is a widely accepted, objective test used in humans and animals for estimation of hearing thresholds and deafness diagnosis. In contrast to humans, testing and recording parameters for determination of normal values for canine hearing are not available. Conflicting information concerning breed and head size effects on canine BAER tests are major contributors preventing this normalization.

The present study utilized standard head measurement techniques coupled with BAER testing and recording parameters modeled from humans to examine the effect canine head size and breed have on BAER results. Forty-three adult dogs from fourteen different breeds had head size measurements and BAER tests performed. The mean latencies compared by breed for waves I, II, III, IV, and V were as follows: 1.46 ± 0.49 ms, 2.52 ± 0.54 ms, 3.45 ± 0.41 ms, 4.53 ± 0.83 ms and 5.53 ± 0.43 ms, respectively. The mean wave I–V latency interval for all breeds was 3.69 ms. All dogs showed similar waveform morphology, structures, including the presence of five waves occurring within 11 ms after stimulus presentation and a significant trough occurring after Wave V. All of the waveform morphology for our subjects occurred with consistent interpeak latencies as shown by statistical testing. All animals had diagnostic results within the expected ranges for each wave latency and interwave interval allowing diagnostic evaluation.

Our results establish that neither differences in head size nor breed impact determination of canine BAER waveform morphology, latency, or hearing sensitivity for diagnostic purposes. The differences in canine head size do not have a relevant impact on canine BAERs and are not clinically pertinent to management or diagnostic decisions.

1. Introduction

Hearing is an important sense allowing animals to accurately perceive their auditory environment. In canines, unilateral hearing loss or complete deafness results in the dog being unable to respond appropriately to sound stimuli. These animals are at greater risk for vehicular injury or abandonment due to subsequent behavioral issues related to their hearing impairment [1–4]. Congenital deafness has

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been reported in over 80 dog breeds [5]. The highest prevalence of canine congenital deafness, estimated up to 30%, [1–8] is noted in the Dalmatian, followed by the Bull Terrier, English Setter, English Cocker Spaniel, Australian Cattle Dog, Norwegian Dunkerhound, and Dappled Dachshund [3–5,8]. Hearing acuity is critical for service, assistance, rescue, police and military working dogs. Working dogs and their handlers depend on the animal's ability to respond appropriately to auditory cues in potentially life-threatening situations [7,9,10]. Thus, accurate hearing assessment is essential to identify dogs with various levels of impaired hearing.

When evaluating canines, veterinary practitioners often use behavioral responses to assess hearing. Behavioral assessment is not an effective method to test hearing because the dog may respond to visual, vibrotactile or olfactory cues instead of the presented auditory stimulus [1,3,9,11–13]. Behavioral tests do not evaluate each ear independently [3–6] nor identify dogs with hearing impairments at specific frequencies [10].

In contrast, the Brainstem Auditory Evoked Response (BAER) is an electrophysiological test employed in humans and multiple animal species to objectively assess auditory function [2,3,9,10,14–21]. In human audiology, BAERs have universally established clinical norms for diagnostic testing, newborn auditory screening and estimation of auditory sensitivity [15–17,20,22]. BAERs assess hearing in each ear independently and can be obtained from awake or sedated subjects [3,4,7,16,18]. BAER tests are also known as auditory brainstem responses (ABR) or brainstem auditory evoked potentials (BAEP) [2–4,9,16,21].

The BAER measures neural responses to auditory stimuli [10,13,16,17]. During BAER testing, a computer generated auditory stimulus is presented into the ear canal of the tested ear [16,19]. The stimulus activates hair cells of cranial nerve VIII to the lower brainstem auditory nuclei in the auditory pathway [3,17]. These auditory evoked potentials are recorded by surface, or subdermal, electrodes on the scalp and appear as a waveform containing a series of five well-defined peaks or waves [1,8,16,19,21–25]. Each wave is generated by certain anatomical portions of the auditory pathway. The exact generator sites specific to each of the five waves have not been confirmed with certainty, especially waves III, IV, and V [16,26]. Waves I and II are thought to emanate from the auditory portion of the vestibulocochlear nerve (CN-VIII) [4,23,27]. Waves III, IV, and V arise from multiple structures of the brain stem including the caudal portion of the auditory pons and neurons mostly located in the superior olivary complex, but additional contributions may come from the cochlear nucleus and nucleus of the lateral lemniscus [4,16,27].

Normal hearing individuals have waveform morphology that can be replicated by repeating the BAER at the same intensity [7,17,28]. In deaf animals, the BAER is often seen as a flat line because no activation of the auditory pathway occurs [3,11]. The BAER threshold is the lowest intensity where clearly defined, repeatable waves are detected after summing BAER responses [9,10,12,13,19].

In puppies, BAERs screen for hereditary hearing impairments in commonly affected breeds. The Orthopedic Foundation for Animals (OFA), a canine advocacy group that establishes control programs to lower the incidence of canine genetic diseases, recognizes BAER-testing as the only accepted method for deafness diagnosis [4,29]. In addition to hearing screening, the BAER can provide estimation of canine hearing thresholds and deafness diagnosis [1,6,9,13]. Serial BAER tests in service and working dogs identify progressive or acquired hearing impairments due to presbycusis, long-term noise exposure, or repeated, sudden-intense impact noise exposure [4,10].

In human audiology, BAER assessment (referred to as Auditory Brainstem Response) is used for diagnosing deficits in the auditory system or determining hearing sensitivity. Human BAER testing is based on consistent data collection by clinicians using similar test parameters in reference to universally established normative values [14,30]. In contrast, no comparable testing standardization or norms exist for the canine BAER [7,9,12,19,26,31,32]. A significant factor hindering the establishment of canine clinical standards is whether head size differences relative to canine breed impact the resultant BAER findings. In people, head size has been determined not to be clinically relevant to BAER morphology or latency [33–38]. However, conflicting evidence regarding whether head size or breed impact canine BAER findings has impeded the establishment of universally accepted normalized canine hearing values [4,7,9,20,24,39–42]. The purpose of this study was to test three hypotheses: 1) canine head size has no clinical relevance on deafness diagnoses or management and 2) canine BAER wave morphology is not dependent on the breed of dog tested, and 3) head size effects on latency are not statistically significant across breeds.

2. Materials and methods

All procedures were approved by the University of Cincinnati Institutional Animal Care and Use Committee and adhered to the National Institutes of Health Guidelines for the Use of Animals in Research.

2.1. Animals

BAER-hearing assessments were completed on 43 client-owned dogs to determine the effect canine breed and head size have on morphology and latencies. The breeds tested included American Bulldog, Beagle, Belgian Tervuren, Border Collie, Bullmastiff, Chihuahua, Dogo Argentino, German Shepherd Dog, Greyhound, Havanese, Labrador Retriever, Pomeranian, Standard Poodle and Welsh Corgi. Owners volunteered their dogs for testing and were not compensated. To assure the auditory system was fully mature, dogs ranged in age from 13 to 120 months. Hearing testing is not performed until a dog is older than 5 weeks because canine postnatal cochlear maturation is not complete until 3 to 4 weeks of age [2–4,8,29]. In humans, adult normative data is used for patients older than 18 months [16,17,22]. Prior to BAER-testing, each owner completed a detailed screening application reviewed by their primary veterinarian which documented vaccine and health status. Upon arrival for BAER testing, a complete physical and otoscopic ear exam were performed by a veterinarian. Dogs with normal otoscopic findings were used in this study. Only one dog was excused due to otitis externa and was never BAER tested. The BAER protocol was completed on each dog in a sound attenuating chamber providing a quiet acoustical environment.

2.2. Head size measurement

To determine the influence of head size on BAER results, the critical measurement and independent variable was the distance between the inverting and non-inverting electrode as altered by the size of the animal's head. For each subject, head width was measured with calipers from the temporal bone portions of the temporomandibular joint, approximately 1 cm anterior to the tragus, referred to as the 'tymp-to-tymp' measurement and from the top of the head to the level of the occipital bone, referred to as 'occ-to-stop' measurement. Caliper values were enumerated with a standard ruler to the nearest 0.1 cm. Measurement of the distance between electrodes was made by calculating the hypotenuse from the inverting and non-inverting electrodes using half of the occ-to-stop and half of the tymp-to-tymp distances from the opposite and adjacent sides of the right triangle formed by the two measurements and then applying the Pythagorean formula: (see Fig. 1) [34,35].

$$\text{Head size} = \sqrt{(tymp - to - tymp/2)} + \sqrt{(occ - to - stop)/2}.$$