

Neurology Neurologie

Brainstem auditory evoked response (BAER) testing in animals

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In today's world of veterinary medicine, veterinary clients expect that their animals will receive high standards of specialized care (1). In companion animal medicine, clients often treat their pet as "one of the family" and expect that veterinarians also make the animal's health a priority in comparison to revenue generated from the animal's care (2). Companion animal owners consider their pet's health and welfare as outcomes for the veterinary services that are provided. As such, though monetary aspects of pet health care are important to consider when devising a diagnostic and therapeutic regime and for

establishing a good client-veterinarian relationship, there is a demand for diagnostic tests that promote the health and well-being of the veterinary patient and that aid in prognosticating disease processes (2).

In veterinary neurology, it is now no longer uncommon to offer relatively noninvasive sophisticated diagnostic testing modalities that include magnetic resonance imaging (MRI), computed tomographic imaging (CT imaging), and electrodiagnostic testing. However, these diagnostic tests do not replace the need to consider and/or perform the most important steps

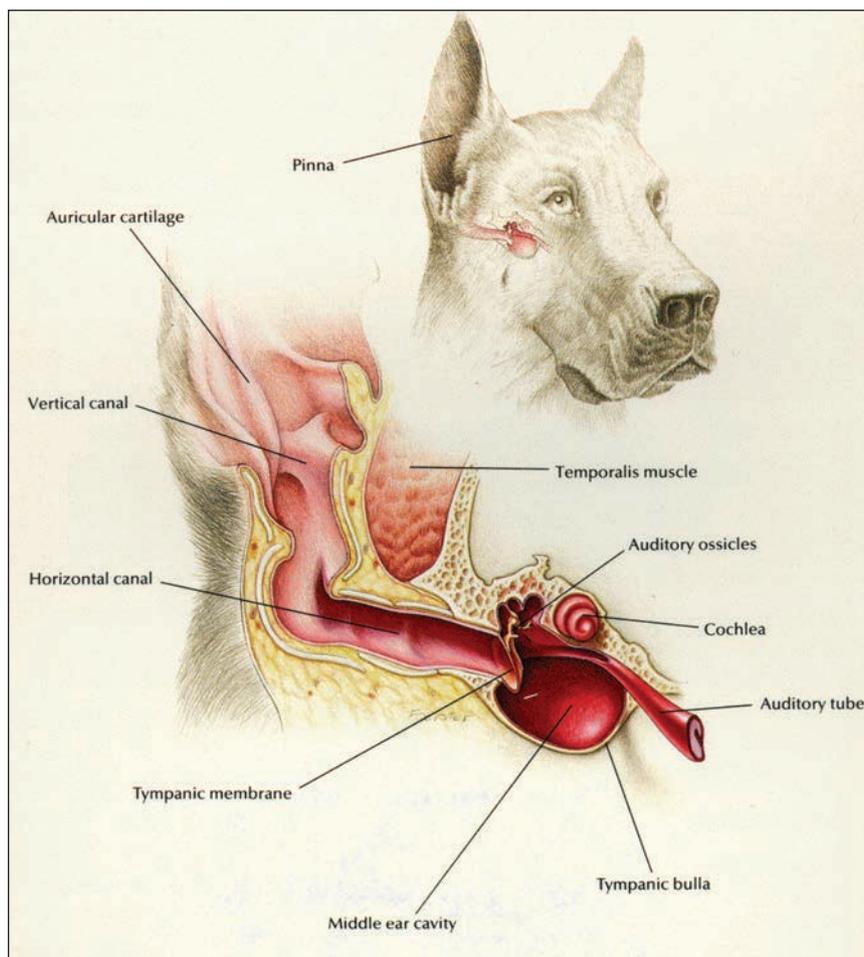


Figure 1. Normal hearing apparatus of the dog. Note the positions of the external, middle and inner components of the hearing apparatus. (Reprinted with permission of Hill's Pet Nutrition, Inc.)

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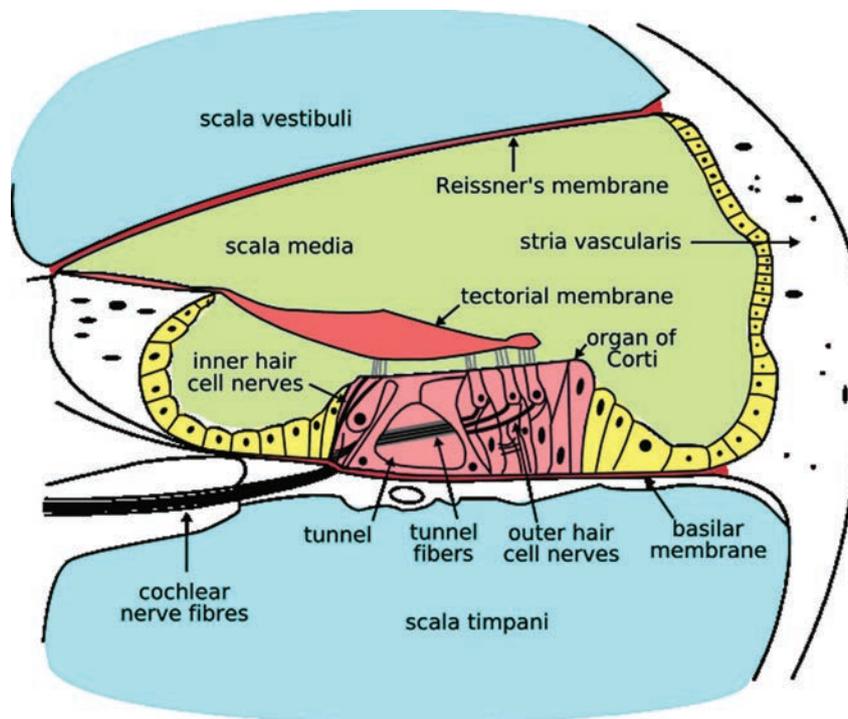


Figure 2. Transverse section through the cochlea. Note the 3 compartments of the cochlea including the scala vestibule (filled with perilymph), the scala media (filled with endolymph), and scala tympani (filled with perilymph). Mechanical vibration of the perilymph causes movement of the basilar membrane. Consequently, the hair cells of the organ of Corti move against the tectorial membrane and are either activated or inactivated to produce an electrical impulse. (This image is licensed under the GNU Free Documentation License and is found in Wikipedia article "Cochlea")

of a neurological workup (signalment, history, physical and neurological examinations); rather, these advanced diagnostic modalities offer the ability to support or confirm presumptive neuroanatomic diagnoses prior to performing more invasive procedures and instituting therapy. The focus of this paper is to discuss the neuroscience and clinical utility of a specific electrodiagnostic test, the measurement of the brainstem auditory evoked response (BAER). Examples of its use in clinical practice and a list of Canadian testing centers are provided.

Anatomy of the ear

Before discussing the physiological and methodological substrates of the BAER, it is important to have a firm understanding of the anatomy of the ear and hearing pathway (Figures 1 and 2). The ear is divided into 3 major compartments — the outer (external) ear, the middle ear, and the inner ear. The outer ear is comprised of the pinna, the auricular cartilage of the vertical and horizontal ear canals and is bounded medially by the tympanic membrane. The middle ear is a relatively hollow air-filled space lined by a mucous membrane and containing 3 bony ossicles (the malleus, incus, and stapes), the ligaments and muscle associated with the ossicles, the sympathetic nerve fibers traveling to the eye originating from the cranial cervical ganglion; it is bounded by the petrous-temporal bone, the auditory bulla, and the tympanic membrane. It should be noted that cranial nerve VII (facial) travels in close proximity through the petrous portion of the temporal bone. The middle

ear communicates with the nasopharynx by way of the auditory tube (Eustachian tube). The inner ear is a complex structure that comprises both the vestibular apparatus and the hearing apparatus. The inner ear is located within the petrous temporal bone of the skull. The hearing portion of the inner ear is made up of the cochlea and the cochlear nerve. The cochlear nerve joins with the vestibular nerve prior to entering the cranial vault and is collectively known as the vestibulocochlear nerve (cranial nerve VIII).

What are the physiologic substrates of hearing?

The ability to hear is brought about by sound waves (oscillating changes in air pressure) that are converted to electrical impulses in the inner ear that are then transmitted to the auditory portion of the cerebral cortex, where sound is perceived. The conversion of sound waves to electrical impulses is a complex process. Herein, the salient physiological mechanisms of auditory transduction (the conversion of sound waves to electrical impulses) and transmission are covered.

Sound waves are mechanical vibrations that can move through a variety of media (air, water). In air, sound waves are composed of rapid oscillations of air pressure. These sound waves are collected and focused by the outer ear. The movement of these air pressure changes causes alternating movement of the tympanic membrane in a proximal-distal direction. The manubrium of the malleus comes into contact with the tympanic membrane and is

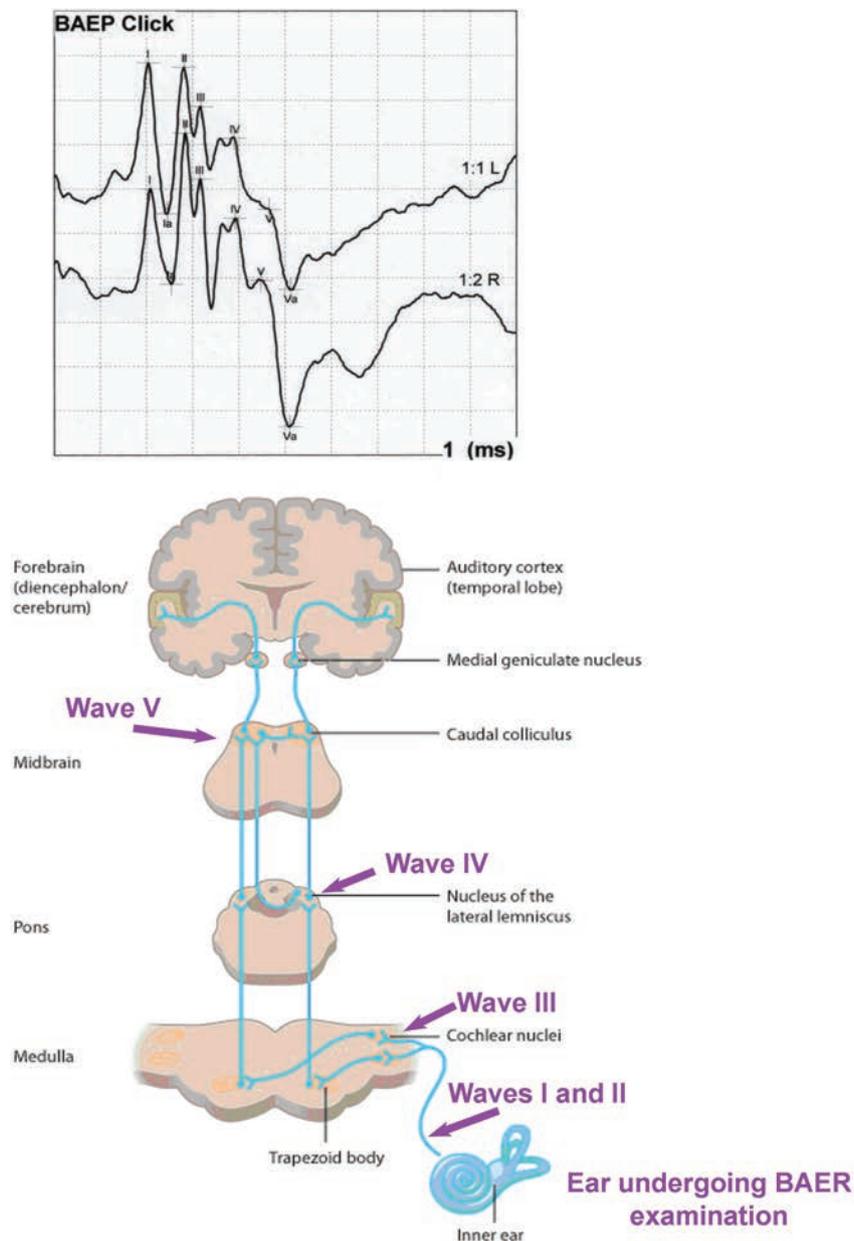


Figure 3. A brainstem auditory evoked response (BAER) tracing in an animal without disease affecting the hearing pathway. Waves I and II are generated by the vestibulocochlear nerve. Wave III is generated by the neurons in or near the cochlear nucleus. Wave IV is generated by neurons in the superior olivary complex in the pons and the cochlear nucleus and nuclei of the lateral lemniscus. Wave V is generated by neurons in the contralateral caudal colliculus of the brainstem (19).

connected by its opposing end to the incus which is articulated with the stapes. Given that the tympanic membrane is moving to-and-fro, this causes movement of the malleus which then causes movement of the incus and then the stapes. The stapes comes into contact with a membranous window of the cochlea known as the oval window.

The cochlea is a closed system and is composed of 3 longitudinally running compartments (the scala vestibuli, scala media, and scala tympani). The scala vestibuli and tympani are continuous with each other and surround the anatomically separate scala media. The oval window looks into the scala

vestibuli and another membranous window (round window) bounds the scala media. The scala vestibuli and tympani are filled with fluid called perilymph while the scala media is filled with endolymph. Movement of the oval window, via movement of the stapes, results in mechanical vibration of the perilymph. Given that the scala media is bordered by flexible membranes (Reissner's membrane and the basilar membrane), mechanical vibration of the perilymph results in movement of a specialized structure called the organ of Corti located within the scala media (Figure 1). The basilar membrane is sensitive to particular frequencies of vibration along its length. This is, in part, how an

Table 1. List of centers offering BAER testing in Canada

Veterinarian	Address	Phone number
Dr. Aubrey Webb	Western Veterinary Specialist Centre and University of Calgary, Calgary, Alberta www.westernvet.ca	403-770-1340
Dr. Gillian Muir	Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan www.usask.ca/wcvm/vth/about.php	306-966-7126
Dr. Roberto Poma	Ontario Veterinary College, University of Guelph, Guelph, Ontario www.uoguelph.ca/vth/	519-823-8830
Drs. Susan Cochrane, Debbie James, Greg Kilburn	Veterinary Emergency Clinic, Toronto, Ontario www.vectoronto.com	416-920-2002
Dr. Joane Parent	Hôpital des animaux de compagnie, Université de Montréal, St. Hyacinthe, Quebec www.medvet.umontreal.ca/chuv/AnimauxCompagnie.html	450-778-8111 ou 514-345-8521 poste 8111 (L'île de Montréal)
Dr. Peter Foley	Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, Prince Edward Island http://www.upei.ca/avc/teaching_hospital	902-566-0950

animal can discriminate between different frequencies (pitches) of sound.

The organ of Corti contains specialized hair cells that are sensitive to bending movements. Given that the hair cells come in contact with a structure called the tectorial membrane, which is held in a fixed place, and that the basilar membrane is moving because of movement of the perilymph, the hair cells come in contact with the tectorial membrane and are bent (Figure 1). This bending causes the hair cells to depolarize and an electrical signal to be generated and ultimately transmitted through the vestibulocochlear nerve and then relayed to the auditory portion of the cerebral cortex where sound is perceived.

What is the BAER?

The brainstem auditory evoked response (BAER) is an electrodiagnostic test that can be broadly classified as an evoked potential. Evoked potentials are electrical potentials that are recorded from an animal after a specified stimulus has been applied. In the instance of the BAER, the stimulus is in the form of sound (clicks, pure tones) or bone conduction stimuli (applying vibrations to the mastoid region of the skull) being delivered to the ear (3–5). In practice, measuring the BAER requires 3 electrodes (recording, ground, and reference), an electrode board (channel board), amplifier, signal averager, and stimulator. No matter the species, the methodology for recording the BAER is similar (6–9). Today, all of these components, including computer software, can be purchased as 1 package by companies specializing in clinical electrodiagnostic equipment. The high cost and specialized nature of electrodiagnostic equipment precludes them from being purchased for general veterinary use, however.

To record a BAER, a noise (usually a multitoneal click in veterinary medicine) is delivered to the ear via earphones, to the ear being stimulated. Alternatively, the cochlea can be stimulated directly by vibrating the bone of the mastoid region (with a

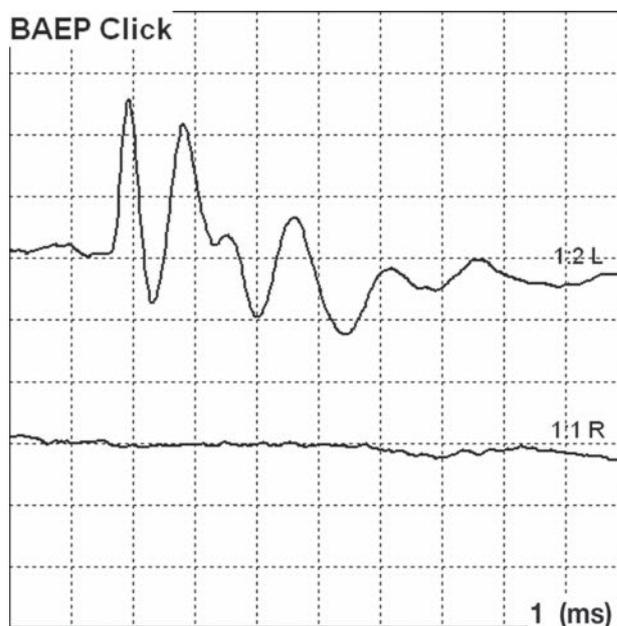


Figure 4. Brainstem auditory evoked responses (BAERs) from a 2-month-old Australian cattle dog with unilateral inherited coat color-related deafness. Notice the appropriate BAER obtained from the left ear (top tracing) while the BAER obtained from the right ear (bottom tracing) is a complete flat-line indicating no generation of electrical activity from the cochlear nerve to the rest of the auditory pathway. (horizontal scale = 1 ms/division; vertical scale = 0.7 μ V/division)

bone stimulator) on the same side as the ear of interest (10). It is important to recognize that animals typically do not need to be sedated or anesthetized, though some clinicians may prefer to use sedation. Each time a stimulus is delivered, the brainwaves are measured and recorded using 2 small gauge subcutaneous needle electrodes — 1 placed at the top of the head and the other placed in front of the ear being examined. A 3rd electrode, the ground electrode, is placed either in front of the contralateral

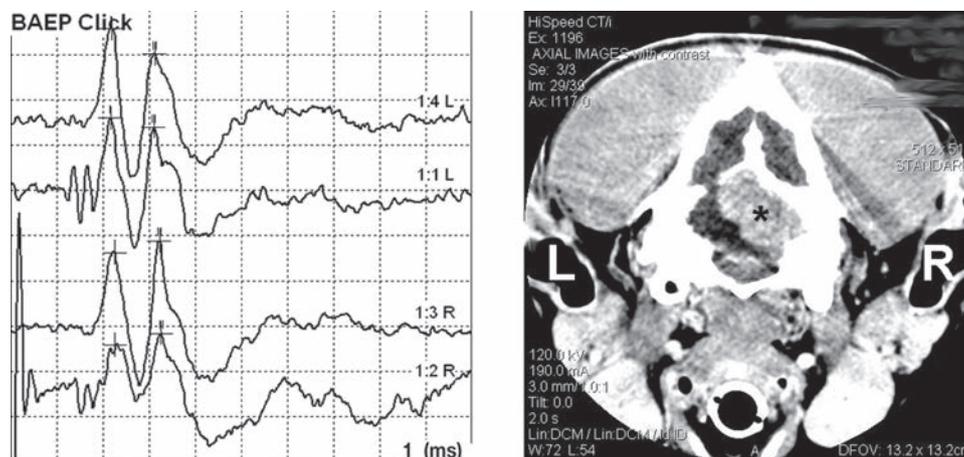


Figure 5. Brainstem auditory evoked responses (BAERs) (image on left) from an 8-year-old boxer dog and a contrast enhanced computed tomographic (CT) axial image (image on right) at the level of the tympanic bullae. The BAERs reveal that only waves 1 and 2 are clearly discernable in the left (top 2 tracings) and the right ears (bottom 2 tracings). Waves III-V are absent in both right and left ears. These findings indicate a failure of electrical impulse generation and propagation at the level of the cochlear nucleus within the medulla oblongata. The BAER was used to support a clinical neuroanatomic lesion location involving the cerebellopontine angle and caudal medulla. These BAER findings resulted from a contrast-enhancing, broad-based mass, located within the caudal fossa and causing bilateral compression of the adjacent neural structures (cerebellum and medulla oblongata) at the level of the cochlear nucleus (asterix) found on CT examination of the dog's head.

ear or placed subcutaneously over the dorsal spinous process of the 1st thoracic vertebra (T1). The amplitude of the BAER is very small and in order to obtain signals that we are interested in, a process called signal averaging must be employed. Several hundred discrete stimuli are delivered (depends on the examiner as to how many) and the computer software averages the electrical responses (brain waves) measured (signal averaging). If one assumes that the measured brainwaves not associated with each “click” occur at random, then the result of signal averaging is that those brainwaves not associated with the click average zero, and we are left with only those brainwaves that are reproducibly associated with the “click” stimulus. The end result of this process is a tracing called the BAER. The BAER consists of 4–6 characteristic waveforms (Figure 3). Each of these waveforms is associated with a particular structure or region along the hearing pathway (Figure 3). In a clinically normal animal, the BAER recorded from each ear is symmetrical. It should be noted, however, that performing and interpretation of BAERs should only be done by specially trained and experienced clinicians (board-certified veterinary neurologists or veterinarians with advanced training in diagnostic electrophysiology) as many factors must be considered when interpreting the BAER (see Table 1 for list of Canadian centers offering BAER examination).

Under what circumstances are BAER examinations performed?

Brainstem auditory evoked response examinations are performed for various reasons. Most commonly, the BAER test is used for assisting in diagnosing various forms of deafness (11). Other reasons may include assisting in neuroanatomically localizing a brainstem lesion, as the BAER can be affected by a variety of processes affecting the central hearing pathways (12).

Deafness is categorized as congenital or acquired, and sensorineural or conductive (13). Congenital forms of hearing loss include conditions where the animal is born deaf or is born with a condition that ultimately results in deafness at maturity [inherited coat color-related deafness (14,15)]. Acquired forms of deafness result when the animal acquires deafness after its normal hearing has developed [exposure of the inner ear to an ototoxic drug (16,17)]. Sensorineural deafness is a form of deafness which is the result of disease processes affecting the neural structures of the hearing pathway (inherited coat color-related deafness). Conduction deafness is that form of deafness that results from failure of conduction of the sound waves to the inner ear (severe otitis externa/media) (18). Figures 4 and 5 represent how the BAER can be used for diagnosing impaired hearing and also to aid in the neuroanatomic location of a disease process.

In summary, it is important to consider referring patients with suspected hearing impairment, or conditions associated with hearing loss, for BAER evaluation. Further, it is important to be cognizant of the general clinical utility and technique of BAER evaluation so as to provide animal owners with pertinent information prior to referring patients for BAER evaluation.

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