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Brain stem auditory potentials evoked by clicks in the presence of high-pass filtered noise in dogs

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Abstract

This study evaluates the effects of a high-frequency hearing loss simulated by the high-pass-noise masking method, on the click-evoked brain stem-evoked potentials (BAEP) characteristics in dogs. BAEP were obtained in response to rarefaction and condensation click stimuli from 60 dB normal hearing level (NHL, corresponding to 89 dB sound pressure level) to wave V threshold, using steps of 5 dB in eleven 58 to 80-day-old Beagle puppies. Responses were added, providing an equivalent to alternate polarity clicks, and subtracted, providing the rarefaction–condensation potential (RCDP). The procedure was repeated while constant level, high-pass filtered (HPF) noise was superposed to the click. Cut-off frequencies of the successively used filters were 8, 4, 2 and 1 kHz. For each condition, wave V and RCDP thresholds, and slope of the wave V latency–intensity curve (LIC) were collected. The intensity range at which RCDP could not be recorded (pre-RCDP range) was calculated.

Compared with the no noise condition, the pre-RCDP range significantly diminished and the wave V threshold significantly increased when the superposed HPF noise reached the 4 kHz area. Wave V LIC slope became significantly steeper with the 2 kHz HPF noise. In this non-invasive model of high-frequency hearing loss, impaired hearing of frequencies from 8 kHz and above escaped detection through click BAEP study in dogs. Frequencies above 13 kHz were however not specifically addressed in this study.

Keywords: Dog; BAEP; BAER; Deafness; HPN masking

1. Introduction

Recording of brainstem auditory potentials evoked (BAEP) by high intensity clicks is a widely used method to detect complete deafness in dogs (Marshall, 1986; Strain et al., 1992; Holliday et al., 1992; Wood and Lakhani, 1997). Click BAEP exhibits four to five positive–negative deflections. Positive peaks are numbered with roman numerals I–V. Wave V is characterized by the deep following trough and the fact that it is the last wave to disappear when the click stimulus intensity is lowered. Exploring the BAEP obtained with the lower range of click intensities makes it possible to identify several forms of less severe hearing losses, among which high-frequency hearing losses in humans. Because they are wide-band stimuli, clicks elicit a response from the frequency region with the best threshold so that BAEP threshold values obviously cannot by themselves provide information about the audiogram (the hearing thresholds as a function of the stimulus frequency) shape.

In the case of high-frequency hearing loss, the wave V threshold elevation is accompanied by a steeper wave V

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latency–intensity curve (LIC) (Gorga et al., 1985), and the intensity range where no difference between the responses to rarefaction and condensation clicks is recorded (pre-RCDP range) is reduced or even abolished (Deltenre and Mansbach, 1993, 1995). The occurrence of such changes needs to be explored in dogs since they may improve the diagnostic value of the readily available click BAEP method. Click BAEP changes in dogs are reported in the literature, and alterations of threshold and wave V latency–intensity curve have been reported in conductive partial hearing loss (Munro and Cox, 1997) but no description of LIC behaviour and click-polarity effects in partial sensory-neural loss is available.

Extrapolating from what is known in other species, several cochlear problems may evolve from the basal cochlear turn, tuned to the high frequencies, towards the apical cochlear turn, tuned to the low frequencies. Among others, sensory presbycusis in old humans (Schuknecht, 1993) and ototoxicities in rodents (McFadden et al., 2002; Segi et al., 2003) follow this scheme.

Noise elevates the threshold of the involved auditory units and reduces their dynamic range up to the point of excluding them from the response (Burkard and Hecox, 1983a,b; Hecox et al., 1989). Superposition of high-pass filtered (HPF) noise to click stimuli makes it possible to non-invasively mimic high-frequency hearing loss by elevating the threshold in selected frequency areas (Parker and Thornton, 1978; Don and Eggermont, 1978; Don et al., 1979; Eggermont and Don, 1980). Modeling a high-frequency hearing loss by high-pass-noise masking assumes a so-called subtractive type of hearing loss (Davis, 1962) in which part of the peripheral sensory units are rendered non-functional so that their usual contribution is subtracted from (or more realistically not added to) the surface-recorded compound response. This implies that the remaining contributing units behave normally. The present study was designed to investigate the changes in BAEP wave V threshold, as well as in two suprathreshold parameters, i.e. LIC slope and pre-RCDP range in the presence of noise HPF at different cut-off frequencies. The purpose was to estimate how far a high-frequency hearing impairment must extend into the low frequencies to become detectable by the click BAEP method in dogs and to evaluate the possible additional diagnostic yield provided by the pre-RCDP range and LIC slope data.

2. Materials and methods

2.1. Animals

Eleven 58 to 80-day-old Beagle puppies (67 ± 7 days, $M \pm$ SD), six females and five males from three different litters were used. Neurologic and otologic examinations were normal, and they did not have received any drug with potential ototoxic effect. They were sedated with medethomidine IM (Domitor, Orion Corp., Espoo, Finland), dosage according to the manufacturer's weight–dose table, and a half dose was added every 60 min. The puppies were placed on a heated pad and body temperature was maintained between 37 and 38 °C. A complete recording session lasted 5–6 h. Atipamezol (Antisedan, Orion Corp., Espoo, Finland) was used to reverse the sedation at the end of the session.

Puppies and their dams were cared for in accordance with the principles established in the National Institute of Health *Guides for Care and Use of Laboratory Animals*, and the study was approved by the Faculty Ethics Committee.

2.2. Stimuli

Square waves 100 μs in duration, generated by a Nicolet Pathfinder II modular electrodiagnostic system, were delivered to a TIP 10 insert earphone (Nicolet Biomedical Instruments, Madison, WI) with a repetition rate of 21.7 Hz.

The digitally constructed filtered noise was delivered through a HFT transducer (Tucker–Davis Technologies, Gainesville, FL). Both transducers were fitted with a 250 mm silicone tubing ending in the same polyurethane foam eartip. Thus, click and noise were acoustically mixed in the auditory canal.

Large band white noise was digitally programmed on a PC. The noise building program included versatile filters, and filtered noise files were generated. A program to verify the filtered noise files content by listing the mean attenuation as a function of the frequency was also prepared.

2.3. Calibration

Calibration was performed using an artificial ear with a 4152 2 ml coupling cavity, fitted with a 4144 calibrated microphone connected to a 2669 preamplifier, Nexus amplifier (all from Brüel & Kjaer, Naerum, Denmark) and digital oscilloscope (Tektronix, Beaverton, OR). The HFT transducer response was investigated by sending sinusoidal waves generated by the SigGen program (Tucker–Davis Technologies, Gainesville, FL). This transducer exhibited a resonance frequency centered at 8 kHz and its response degraded beyond 14 kHz; both findings were in agreement with the manufacturer's data.

2.4. Noise filtering

The wide band noise was first filtered to compensate for the transfer function (resonance centered at 8 kHz) of the buffer driver/high frequency transducer used to deliver it, in order to obtain constant mean noise amplitude.