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Vestibular-evoked myogenic potentials in miniature pigs

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Abstract

Objective: To report detection of vestibular-evoked myogenic potentials (VEMPs) in the miniature pig.

Methods: Potentials evoked by 1000 Hz tone bursts were recorded from neck extensor muscles and the masseter muscles in normal adult Bama miniature pigs anesthetized with 3% pentobarbital sodium and Carbachol II.

Results: The latency of the first positive wave P from neck extensor muscles was 7.65 ± 0.64 ms, with an amplitude of 1.66 ± 0.34 uv and a rate of successful induction of 75% at 80 dB SPL. The latency of potentials evoked from the masseter muscles was 7.60 ± 0.78 ms, with an amplitude of 1.31 ± 0.28 uv and a rate successful induction of 66% at 80 dB SPL.

Conclusion: The latencies and thresholds of VEMPs recorded from the neck extensor muscle and the masseter muscle appear to be comparable in normal adult Bama miniature pigs, although the amplitude recorded from the neck extensor muscle seems to be higher than that from the masseter muscle. However, because of their usually relatively superficial and easily accessible location, as well as their large volume and strong contractions, masseter muscles may be better target muscles for recording myogenic potentials.

Keywords: Vestibular evoked myogenic potentials; Miniature pig; Masseter myogenic potential

1. Introduction

Vestibular-evoked myogenic potentials (VEMPs) is an objective and accurate method to assess vestibular functions via recording the myogenic potential from the sternocleidomastoid muscle evoked by high intensity acoustic stimulation of the ipsilateral saccule (Shimizu et al., 2000). VEMPs may be used for diagnoses and prognoses purposes with high specificity in a number of diseases including sudden hearing loss, Meniere's disease and vestibular neuritis. VEMPs are divided into ocular vestibular-evoked myogenic potentials (oVEMPs) and cervicalves vestibular-evoked myogenic potentials (cVEMPs), depending on the specific neural transmission pathway.

Miniature pigs are comparable to humans in both anatomy and physiology. Advantages of using miniature pigs include their relatively light bodyweight, slow rate of growth and overall convenience in experimental operations. They have been used in studies involving tumors, cardiovascular diseases, diabetes, oral surgeries, plastic surgeries, hematologic diseases, genetic and metabolic diseases, and drug safety

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evaluation (Guo et al., 2015). The miniature pig is now beginning to be applied to inner ear studies. Compared to other rodent animals, the miniature pig has unique advantages in terms of ear anatomy: (1) The miniature pig has a complete middle ear and mastoid air cells system. (2) Its ear morphology, ossicular chain size and cochlear microstructure are similar to those of humans. (3) The morphology and structures of its vestibular system are also similar to those of humans. These make the miniature pig the best animal model for VEMP testing. While a few studies have reported VEMPs in guinea pigs and mice, none have applied the test to miniature pigs. This study examines VEMPs in the miniature pig.

2. Materials and methods

2.1. Experimental animals

Six months old female Bama pigs (n = 12, weight 25 kg) with completely normal hearing and balance functions were used for VEMP tests.

2.2. Anesthesia

Pentobarbital sodium, which has no effect on muscular resistance, was combined with Carbachol II for anesthesia: Carbachol II was injected into the neck muscle (0.1 ml/kg) and 3% pentobarbital sodium was administered through intravenous injection (1 ml/kg) at 2 ml/min. Anesthesia took effect within 10 min, marked by loss of corneal reflex. Because anesthesia would induce muscle relaxation, which affects the contraction of skeletal muscles, VEMPs were recorded from the same muscle under both relaxation and tension conditions for comparison. ABR tests were performed to ensure that there were no significant contaminations by hearing responses (Weiwei et al., 2015).

2.3. VEMP and ABR tests

VEMPs recorded from the sternocleidomastoid muscle are commonly used in the clinic to evaluate vestibular functions, especially saccular functions. This method excludes elderly patients and patients with cervical diseases because it requires extensive contraction of the sternocleidomastoid muscle. The miniature pig neck extensor muscle is similar with the human sternocleidomastoid muscle in anatomy and function. The neck extensor muscle is the thickest muscle on both sides of the neck. It originates from the humerus crest and terminates at the occipital bone and petrous. Due to thick adipose tissue found around the miniature pig neck, the neck extensor muscle is difficult to access. Recently, the masseter muscle has been used to record VEMPs in elderly patients and those with cervical spondylosis for vestibular reflex evaluation. Xie (Sujiang, 2007) recorded masseter myogenic potentials evoked in awake guinea pigs. The miniature pig masseter muscle starts in the cheekbone and ends in the lateral surface of the mandible, covered by facial muscle and facial nerve. It is a short and thick muscle in an approximately square shape. The deep surface of the masseter muscle is lateral to the mandibular ramus (Zhu et al., 2004). The masseter muscle is reasonably easy to access. In this study, we recorded VEMPs from both the neck extensor and masseter muscles in the miniature pig.

The SmartEP (Intelligent Hearing Systems, USA) was used to record the muscle potential in an open sound field with a 30-3 kHz band-pass filter setting and 30 k EMG signal amplification. The analysis window was 50 ms and electrode resistance <3 kΩ, with superposition of 128 responses to short sound stimulation at 1000 Hz. Stimulus intensity started at 120 dB SPL and was decreased in 5 dB increments until the reproducible waveform disappeared. Two consecutive records were acquired to ensure repeatability. A custom-made silver needle electrode (silver nickel alloy of 90% purity, 0.9 × 50 mm) covered with Teflon was used for recording. A current meter was used to test the electrode.

2.3.1. Neck extensor muscle VEMPs

VEMPs were recorded from the neck extensor muscle first in a relaxed state. The miniature pig was then positioned on the side on the test bench with the head turned to the other side at a 45° angle. A special device was used to maintain tension in the neck extensor muscles, prior to measurement of myogenic potentials. To prevent airway blockage, the tongue was pulled out of the mouth before the test. The recording electrode was placed at the bifurcation of the neck extensor muscle. The reference electrode was inserted into the top of the head at the surface of the ridge crest periosteum. The grounding electrode is inserted into the proboscis (2 cm in depth, <3 kΩ in resistance). VEMP waveforms under various sound stimulus intensities were visually examined and the threshold was determined as the stimulus intensity associated with the disappearance of the first positive P wave.

2.3.2. Masseter muscle VEMPs

Similar with neck extensor muscle VEMP recording, masseter muscle VEMPs were also first recorded in a relaxed condition. A roll of gauze wrapped around a stick was then placed in the mouth to create tension in the masseter muscle before recording myogenic potentials was repeated. The recording electrodes was inserted roughly a third of the way into the masseter muscle on the test side. Reference and ground electrodes placement was similar to neck extensor muscle VEMP recording. VEMP waveform examination and threshold determination were also similar to those for neck extensor muscle VEMPs.

2.3.3. Auditory brainstem response

The recording electrode was inserted into the top of the skull. The reference electrode was placed on the recording side earlobe. The ground electrode was connected to the nose tip. Impedance between electrodes was less than 3 kΩ. Clicks stimulation was started at 100 dB SPL and decreased to 20 dB SPL by 10 dB steps. Filter setting was 100–3000 Hz. ABR threshold was the stimulus intensity associated with disappearance of wave V.