International Journal of Pediatric Otorhinolaryngology (2009) **73**, 371—375

ELSEVIER

International Journal of Pediatric Otorhinolaryngology

www.elsevier.com/locate/ijporl

The effect of increased inner ear pressure on tympanic membrane vibration

Chul Ho Jang [a,b,*], Haekyun Park [b], Cheol Hee Choi [b], Yong Bum Cho [a], Il Yong Park [c]

[a] *Department of Otolaryngology, Chonnam National University Medical School, Gwangju, South Korea*
[b] *Research Center for Resistant Cell, Chosun Medical School, Gwangju, South Korea*
[c] *Department of Biomedical Engineering, Dankuk Medical School, Cheonan, South Korea*

Received 27 August 2008; received in revised form 30 October 2008; accepted 4 November 2008
Available online 30 December 2008

KEYWORDS
Inner ear pressure;
Laser Doppler vibrometer;
Umbo;
Vibration

Summary

Background & Objective: It has been suggested that increased inner ear pressure can affect the stiffness of the tympano-ossicular conductive system. However, the published literature contains few studies on changes of middle ear mechanics caused by increased inner ear pressure. In this study, we evaluated the effects of increased inner ear pressure on tympanic membrane vibration in guinea pigs using a laser Doppler vibrometer (LDV).
Materials and Methods: We used 10 male guinea pigs (weighing 250 g each) with normal eardrums and Preyer reflexes were used for the experiment. Inner ear pressure was modified by two approaches—directly via a tube placed in the inner ear ($n = 5$) and indirectly via a tube placed in the subaracnoid space ($n = 5$). Slow uniform pressure (μl/min) was infused until constant pressure was maintained. At this time, an artificial endolymph or perilymph was injected with a constant pressure of 100 and 300 mmH2O. We measured the umbo velocity using a LDV.
Results: A positive pressure load decreased the umbo vibration at low frequencies but did not change the umbo vibration at mid and high frequencies. The umbo velocity had a greater reduction for an endolymphatic pressure load than for a perilymphatic pressure load. The largest change in velocity was noted at a frequency of 0.1 kHz. There was no significant change in velocity at higher frequencies, except for 5 kHz.
Conclusion: LDV is a good tool to analyze middle ear function and it has the potential indirectly to diagnose an increase in endolymphatic or perilymphatic pressure.

* Corresponding author at: Department of Otolaryngology, Chonnam National University Hospital, Hakdong 8, Gwangju 501-190, South Korea. Tel.: +82 62 2206774.
E-mail address: chulsavio@hanmail.net (C.H. Jang).

0165-5876/$ — see front matter
doi:10.1016/j.ijporl.2008.11.006

1. Introduction

Understanding the auditory dysfunction associated with endolymphatic hydrops or perilymphatic hypertension is a complex issue as these pathological states induce multiple alterations in the inner ear, including osmotic and chemical balance, blood flow, electrophysiology and intralabyrinthine pressure. Loss of low-frequency acoustic sensitivity has been noted in hydropic guinea pigs undergoing various electrophysiological studies. The endocochlear potential, summating potential, action potential and cochlear microphonics are affected by artificial and nonphysiological manipulations of endolymphatic and perilymphatic pressures [1—5]. Transmission of increasing cerebrospinal fluid (CSF) pressure to the inner ear can induce hearing impairment. Experimentally, suppression of cochlear microphonics has been observed in cats with increased CSF pressure [2,6]. Tonndorf [7] showed in experiments with cochlear models that an increase in the endolymph volume caused a decrease in the basilar membrane displacement that was proportional to the cochlear microphonic response; the decrease was greater for lower frequencies than for higher frequencies. An increase in either perilymphatic or endolymphatic pressure seems to produce similar effects on hearing thresholds. The effect of an increase in inner ear pressure on cochlear microphonics response at low frequencies is thought to be caused by an increased overall stiffness of the inner ear mechanical sound transduction mechanism. It remains to be elucidated if the mechanism for hearing loss in hydrops is pressure related or is due to direct mechanical or biochemical changes imparted throughout the cochlea.

It has been suggested that increased inner ear pressure can affect the stiffness of the tympanoossicular conductive system [8,9]. Zwislocki [10] and Moller [11] showed experimentally that the cochlea has its greater effect on middle ear impedance, as measured at the tympanic membrane, in the 0.5 to 1.0-kHz frequency range. Marchbanks and Reid [12] reported a method to determine indirectly abnormal intracranial and intracochlear pressure by changes in the stapedius reflex resulting from a change in mobility of the stapes footplate.

The use of laser Doppler vibrometry (LDV) has a much greater sensitivity (10,000 times higher) as compared to tympanometry. LDV allows one to measure extremely small displacement amplitudes and velocity amplitudes in the nanometer range. However, the published literature contains few studies describing changes of middle ear mechanics by increased inner ear pressure using LDV [13,14]. In this study, we evaluated the effects of increased inner ear pressure on the tympanic membrane vibration in guinea pigs using LDV.

2. Materials and methods

All animal experiments were performed in accordance with the local ethical committee at Research Center for Resistant Cells, Chosun University. We used 10 male guinea pigs (weighing 250 g each) with normal eardrums and Preyer reflexes were used for the experiment. Inner ear pressure was modified by two approaches—directly via a tube placed in the inner ear (n = 5) and indirectly via a tube placed in the subarachnoid space (n = 5). Endolymphatic pressure was elevated by direct placement of a catheter into the endolymphatic space via lateral semicircular canal fenestration. A 28-gauge polyurethane tube (Alzet, Cupertino, CA, USA) was inserted into the lateral semicircular canal via a small hole (1 mm

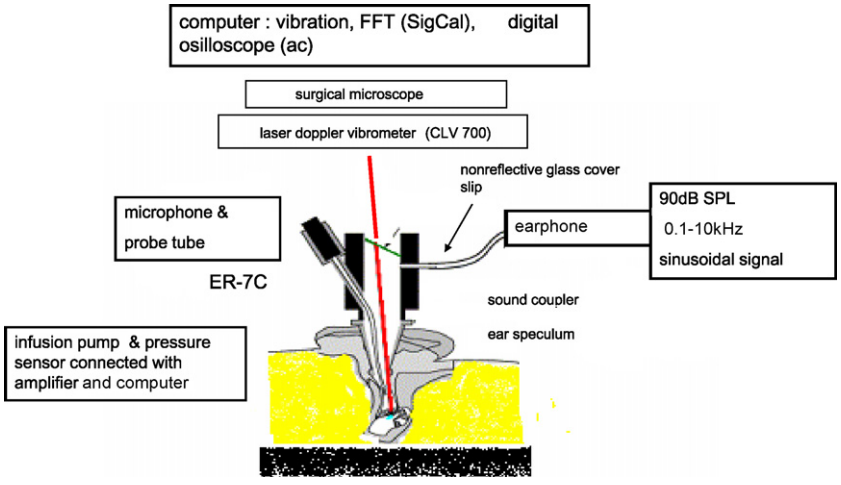

Fig. 1 Schematic view of the umbo vibration measuring system.