Effect of Artificial Endolymph Injection into the Cochlear Duct on Perilymph Potassium

Akinobu Kakigi^{a, b} Alec N. Salt^c Taizo Takeda^b

^aDepartment of Otolaryngology, Faculty of Medicine, University of Tokyo, Tokyo, and ^bDepartment of Otolaryngology, Kochi Medical School, Kochi, Japan; ^cDepartment of Otolaryngology, Washington University School of Medicine, St. Louis, Mo., USA

Key Words

Endolymphatic hydrops • Artificial endolymph injection • Perilymph potassium ion • Vertigo attack • Ménière's disease

Abstract

Objective: To investigate the relationship between endolymphatic hydrops and perilymphatic potassium. **Methods:** 20 pigmented guinea pigs were used: 10 for scala vestibuli study and 10 for scala tympani study. Acute endolymphatic hydrops was produced by microinjection of an artificial endolymph into the scala media. Injections were performed in the second turn at rates up to 500 nl/min for a period of 10 min. The injection volume was up to 5 μ l. Endocochlear potential (EP) was monitored during injections. Simultaneous with the injections, the potassium concentrations in scala vestibuli (K_{SV}) or tympani (K_{ST}) perilymph were measured with ion-sensitive double-barreled microelectrodes sealed into the scalae in the 3rd turn with cyanoacrylate glue. **Results:** For endolymphatic injections of ≤ 3 μ l, perilymphatic K_{SV} and K_{ST} changes were generally small. With larger volume injections, substantial increases in both K_{ST} and K_{SV} were observed, with larger increases observed in K_{SV} compared to K_{ST} . **Conclusion:** An increase of perilymph potassium ion concentration is associated with endolymphatic hy-

drops and the perilymphatic increase could contribute to the inner ear dysfunction of patients with Ménière's disease. Although mild hydrops may not cause perilymphatic changes, extended hydrops may increase perilymphatic K which could contribute to vertigo and/or hearing loss during the attack.

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Introduction

The pathological feature of Ménière's disease is endolymphatic hydrops. However, the causes of symptoms during Ménière's attacks remain unclear. Although there is some evidence that the Ménière's attack may be mechanical in origin [1], one hypothesis is that endolymphatic hydrops causes a perilymphatic potassium increase and the potassium has a toxic effect on the eighth nerve [2, 3]. The results from temporal bone histopathology of Ménière's disease that include the rupture of the Reissner's membrane support this hypothesis. If it is the case, high K^+ of endolymph should leak into the scala vestibuli. The higher K^+ in scala vestibuli could propagate into scala tympani through the spiral ligament and, in apical regions, through the helicotrema. However, the cause of K^+ leakage from the endolymph could occur not

only from a rupture of the Reissner's membrane but also from a permeability change of the cochlear duct without rupture, suggested by observations that Reissner's membrane ruptures are not observed in all temporal bones following attacks. The purpose of this study was to investigate the relationship between endolymphatic hydrops and perilymphatic potassium under conditions without Reissner's membrane rupture.

Materials and Methods

Twenty pigmented guinea pigs were used: 10 for scala vestibuli study and 10 for scala tympani study. The animals were deeply anesthetized with xylazine hydrochloride 2.4 mg/kg i.m. and ketamine hydrochloride 15 mg/kg i.m. The temporal bulla was opened and the cochlea was exposed by a ventral approach. An acute endolymphatic hydrops was produced by microinjection of an artificial endolymph into the scala media. Injections were performed in the second turn at rates up to 500 nl/min for period of 10 min. The injection volume was up to 5 μ l. The composition of artificial endolymph was (in mM) KCl 140 and KHCO_3 25 (295–300 mosm). Endocochlear potential (EP) was monitored during injections. Simultaneously, the potassium concentrations in scala vestibuli (K_{SV}) or tympani (K_{ST}) perilymph were measured with ion-sensitive double-barreled microelectrodes sealed into the 3rd turn with cyanoacrylate adhesive.

Results

For endolymphatic injections of ≤ 3 μ l, perilymphatic K_{SV} and K_{ST} changes were generally small. Interestingly, K_{ST} changes were negative with a <0.8 - μ l injection. With larger volume injections, substantial increases in both K_{ST} and K_{SV} were observed, with larger increases observed in K_{SV} compared to K_{ST} (fig. 1). Figure 2 shows the K_{ST} and EP change with a 0.7- μ l injection. K_{ST} decreased 0.34 mM after injection, and EP increased 1.8 mV after injection.

Discussion

In this study, we investigated the relationship between endolymphatic hydrops and perilymphatic potassium. With a smaller volume of endolymphatic injections, perilymphatic K_{SV} and K_{ST} changes were generally small. Such a small volume injection would produce only mild endolymphatic hydrops with an increase of the EP [4]. Since mild hydrops has little influence on the perilymphatic potassium concentration, this would be an unlikely

Fig. 1. Perilymph K^+ changes as a function of volume injected into the endolymphatic space. For ≤ 3 μ l, perilymphatic K_{SV} and K_{ST} changes were generally small. Interestingly, K_{ST} changes were negative with a <0.8 - μ l injection. With larger-volume injections, substantial increases in both K_{ST} and K_{SV} were observed. dK_{ST} = K^+ change in scala tympani; dK_{SV} = K^+ change in scala vestibuli.

Fig. 2. K_{ST} and EP changes with a 0.7- μ l injection. K_{ST} decreased 0.34 mM after injection. EP increased 1.8 mV after injection. EP = Endocochlear potential; K_{ST} = potassium concentrations in scala tympani perilymph. Thick bar = artificial endolymph injection for a period of 10 min.

source of any dysfunction associated with mild hydrops. Interestingly, K_{ST} changes were negative with <0.8 μ l injection. This decrease of K^+ may be caused by a displacement of the basilar membrane. When the basilar membrane shifts toward scala tympani, the transducer channels will close and the potassium current toward scala tympani will decrease. These may be the mechanisms of K_{ST} decrease with a small-volume injection.

With larger-volume injections, substantial increases in both K_{ST} and K_{SV} were observed, with larger increases observed in K_{SV} compared to K_{ST} . These results suggest that substantial hydrops, as is often present in Ménière's disease, could result in increased perilymphatic potassium concentration, which could contribute to auditory and vestibular dysfunction. Salt and Ohyama [5] reported that with acute manipulations of perilymph K^+ there was a rapid clearance of K^+ from the perilymph. This study also showed that K^+ clearance from scala tympani was faster than that from scala vestibuli. The smaller potassium change observed in scala tympani in the present

study is consistent with a faster rate of potassium clearance from that scala. These results show that an increase of perilymph potassium ion concentration is associated with endolymphatic hydrops and the perilymphatic increase could contribute to the inner ear dysfunction of patients with Ménière's disease.

Disclosure Statement

The authors are not aware of any conflict of interest or similar issue that may be relevant to the present work.

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