Introduction

BPPV is the most common vestibular disorder with good prognosis. The pathophysiology has been debated for long time, but recently canalolithiasis has been credited as the most potential mechanism since physical maneuver and posterior canal plugging operation were developed (Epley 1997; Parnes und McClure 1992). However, there are some cases that resist treatments or recur for many times. The mechanism of these cases should be further investigated. One of the feasible approach to pathophysiology of BPPN is to study basic vestibular structure, such as otolith and cupula. In this paper, basic aspects of the otolithic organ and the semicircular canal (SC) cupula as well as model experiments using the isolated labyrinth are presented.

This paper consists of two major parts, one is morpho-physiological properties of cupula and semicircular canal, and the second is model experiments of BPPV.

Morpho-physiological properties of cupula and semicircular canal

This section includes 4 topics, 1: Sensitivity of cupula surface, 2: Removal and replacement of cupula, 3: Physiological localization of SC receptors. 4: Change of cupula shape due to aminoglycosides. Most of these experiments were performed using bull frog labyrinths. There are several reasons of using frog’s labyrinth. First, the labyrinth with rather tough membrane tolerates experimental manipulation. Secondly, vestibular sensory cells can survive in Ringer’s solution for several hours after decapitation. Thirdly, frog’s vestibular organ is very similar to that of the mammals. Finally, it has been used intensively for vestibular research for many years.

Fig. 1
Points of stimulation on the cupula surface. The cupula surface of the utricular side of PC was divided into 3 sections. Three points from the base to the top were selected in each section.
**Sensitivity of cupula surface**

Sensitivity of the cupula surface as a mechanical transducer was studied using isolated posterior semicircular canal (PC) (Suzuki und Harada 1985). The membranous wall was cut around the ampullary dome and was removed, thus exposing the entire cupula as is attached to the crista with the base.

Nine points of the cupula surface of the utricular side were selected as stimulus points (Fig. 1). Each point was mechanically depressed using a fine glass pipette for 10 μm and the PC ampullary action potentials (CAP) were recorded via glass suction electrode. Three points at the cupula base yielded the greatest potentials in terms of the maximum spike counts. The CAP of other points were expressed in percentage with that of the center-base point as 100%. The CAP decreased as the stimulus points go to the cupula top (Fig. 2), resulting in about 50% at the top 3 points. There is a gradient of response sensitivity on the cupula surface. This indicates that BPPV symptom may differ according to the location of the otolith attached on the cupula which is known as cupulolithiasis.

**Removal and replacement of the cupula**

The cupula was removed using a fine glass hook from the crista (Suzuki et al. 1984). CAP in response to mechanical endolymphatic flows with 5 grades were compared before and after the cupula removal. Also, CAP were recorded when the cupula was replaced back on the crista. Before the cupula removal, CAP were recorded that increased according to the stimulus increase. After the cupula removal, no CAP was seen, although the spontaneous discharge remained. When the cupula was replaced, CAP well recovered, but the response to the smallest stimulus was extremely small (Fig. 3). This indicates the contact between the cupula base and the crista, particularly insertion of the long cilia into the cupula body is most essential for sensory cell activation. When the cupula was turned over and replaced, so that the cupula top faces the crista, the CAP markedly reduced. This is because the cupula shape tapers toward the top, thus markedly reducing the contact between the cupula and the crista.

**Physiological localization of semicircular canal receptors.**

The distribution of the time constants of SC CAP in response to direct stimulation to the sensory cilia was mapped out across the crista surface (Suzuki et al. 1986). The cupula of PC was removed to expose the crista surface. Seven points on the crista surface were selected for stimulation. The cilia were depressed by 30 μm using a fine glass pipette to provoke CAP. The decremental time constant of PC was the longest at the two most lateral points (10.8 sec and 8.9 sec in average). It progressively shortened toward the central point (2.8 sec in average), resulting in a V shaped curve (Fig. 4). Since the cilia are generally longer at the lateral part, the cilia length is involved in the degree of adaptation. However, the present results indicate a possibility of adaptation of sensory origin, since the depression amount to the cilia was...