Effects of caloric stimulation on frog ampullar receptors

B. GIANNONI, S. VALLI

Since the beginning of the century caloric testing is the most widely used in clinical practice to evaluate the Vestibulo-Ocular Reflex (VOR).

In spite of this, the effective mechanism of thermal stimulation of labyrinthine receptors is not still definite. The observation that caloric nystagmus can be evoked in microgravity argues against Barany's convective theory as the unique mode of thermal activation of vestibular receptors.

When a temperature change is brought to the labyrinth probably more than one mechanism is involved in receptor's stimulation: 1) temperature variation induces endolymphatic convective currents able to cause inhibition or excitation of the ampullar receptors by means of a mechanical cupular deflection (Barany's theory); 2) heating or cooling of the membranous semicircular canal causes a local expansion of the endolymphatic volume that may vary the resting activity of the ampullar receptors by deforming the cupular complex; 3) electrical activity of the hair cells and/or the afferent vestibular nerve fibers is varied by the direct effect of temperature on these structures.

Although convective currents are believed to be the main mode of activation of vestibular receptors when gravity is present however the relative importance of the other two non-convective mechanisms is not clear at all.

Recently we got ready a new method able to generate controlled thermal-induced responses of ampullar receptors to caloric stimuli. As a model we used the whole labyrinth of the frog (Rana Esculenta); caloric stimulation was brought to the posterior semicircular canal by means of a little heating probe.

Using this model we tried to evaluate the effects of caloric stimulation directly deriving responses from the ampullar receptors, that represent the entrance of the VOR.

The aim of the present study was to try to understand the effective contribution of each different mechanism involved in caloric vestibular response.

In our experiments the stimulus produced a gravity dependent transcupular pressure difference that, depending on the position of the heater, could result in either excitation or inhibition of ampullar receptor sensory discharge.

When the heater was positioned over the ampulla, or when the canal laid in the horizontal plane, no responses could be evoked by thermal stimuli. These results suggest that, in our experimental conditions (Δ up to 1.5°C), neither a thermally induced expansion of the endolymph nor a direct action of the temperature on vestibular sensors play any major role.

We also tried to obtain a better knowledge of modifications induced in the sensorineural activity of canal receptors by thermal changes (in terms of amplitude, duration, temporal course , adaptive processes of the response and thermal sensibility) to allow a deeper evaluation of the caloric induced nystagmus and therefore of the processes involved in the VOR itself.

References

1. BARANY R.: *Untersuchungen uber dem vom vestibulapparat des Ohres reflektorisch ausgelosten rhytmischen nystagmus und seine Begleiterscheinungen.* Monatschr Ohreinlheilk (Berlin) 40:193-297, 1906.
2. GENTINE A., EICHORN J.L., KOPP C., CONRAUX C.: *Modelling the action of caloric stimulation of the vestibule. I: The hydrostatic model.* Acta Otolaryngol. (Stockh) 110:328-333, 1990.
3. GENTINE A., EICHORN J.L., KOPP C., CONRAUX C.: *Modelling the action of caloric stimulation of the vestibule. II: The mechanical model of the semicircular canal considered as an inflatable structure.* Acta Otolaryngol. (Stockh) 111:10-15, 1991.
4. GENTINE A., EICHORN J.L., KOPP C., CONRAUX C.: *Modelling the action of caloric stimulation of the vestibule. III: Caloric nystagmus induced by osmotic pressure variations.* Acta Otolaryngol. (Stockh) 111:463-467, 1991.
5. GENTINE A., EICHORN J.L., KOPP C., CONRAUX C.: *Modelling the action of caloric stimulation of the vestibule. IV: The global mechanical model.* Acta Otolarynogl. (Stockh) 111:633-638, 1991.
6. HOOD J.D.: *Evidence of direct action upon the vestibular receptors in the caloric test.* Acta Otolaryngol. (Stockh) 107:161-165, 1989.
7. SHERER H., CLARKE A.H.: *The caloric vestibular reaction in space.* Acta Otolarynogl. (Stockh) 100:328-336, 1985.
8. SUZUKI M., KADIR A., HAYASHI N., TAKAMOTO M.: *Direct influence of the temperature on the semicircular canal receptor.* J. Vest. Res. 8:169-173, 1998.
9. ZENNER H.P., ZIMMERMANN U.: *Caloric evoked motile responses of mammalian vestibular sensory cells.* Acta Otolaryngol. (Stockh) 115:484-487, 1995.
10. ZUCCA G., BOTTA L., VALLI S., GIANNONI B., MIRA E., PERIN P., VALLI P.: *Caloric stimulation of ampullar receptors: a new method to produce mechanically evoked responses in frog semicircular canals* (in press; J. Neurosc. Methods) 1999.