

Subjective Visual Horizontal Determination During Otolith Stimulation by Eccentric Rotation in Conservatively Treated Meniere's Disease

Lars M. Ödkvist, M.D., Ph.D., Lisbeth Noaksson, Susanne Olsson, and Torbjörn Ledin, M.D., Ph.D.

Department of Ear, Nose, and Throat, University Hospital, Linköping, Sweden

Abstract: Peripheral vestibular equilibrium disorders may originate in various parts of the labyrinth or of the vestibular nerve. Traditionally, the function of the lateral semicircular canals has been assessed by caloric irrigation and has been interpreted (sometimes falsely) as demonstrating a vestibular nerve lesion. The vertical semicircular canals are not assessed easily. Caloric testing with the head in various positions is not very helpful, but the canals may be tested in pairs using specific rotational techniques. Often, the otolith organs, detecting linear acceleration forces, are forgotten as a source of vertigo and dizziness. The extent of otolith involvement in Meniere's disease is not well understood.

The tested subject is seated eccentrically in a rotatory chair and faces the direction of rotation. Thus, the otolith organs are stimulated in steady-state rotation. The subject experiences a lateral tilt and, in darkness, is instructed to point a short light bar in the position that he or she thinks a water surface would have (identical to the perceived tilt). Patients with conservatively treated unilateral Meniere's disease were tested.

In the eccentric rotation test, the patients with unilateral Meniere's disease showed highly variable, sometimes even paradoxical, responses. No correlation was noted between the eccentric otolith test and pure-tone audiometry or the side difference of the caloric responses.

Otolith and lateral semicircular canal functions may differ in patients with Meniere's disease, the nature of which remains to be elucidated in further studies.

Traditionally, patients with Meniere's disease are evaluated by their symptoms and the pure-tone audiogram in follow-up of their disease. Increases in vestibular knowledge in the medical community have been accompanied by an increased interest in following also the caloric response side difference, as defined by Jongkees. In this study, we have investigated the value of a new test that estimates the function

of the peripheral vestibular organs, assessing the force-detection function of the otoliths.

The otoliths are arranged in the saccule and utricle to detect linear acceleration forces in three dimensions. Eccentric rotatory testing—with the subject seated some distance from the rotation center facing the direction of rotation—will provide a constant lateral acceleration stimulus, which is detected by the otoliths. The effects of the initial angular acceleration will cease some time after the rotation has reached a constant speed. To exclude visual cues to the true orientation of the subject, the rotation takes place in complete darkness. Though the pressure from the chair on the body and shoulder is obvious, subjects will experience a strong sensation of lateral tilt. They then may give a subjective estimate of how an imagined horizontal sur-

Reprint requests: Torbjörn Ledin, M.D., Ph.D., Department of Ear, Nose, and Throat, University Hospital, S-581 85 Linköping, Sweden. E-mail: torbjorn.ledin@oto.us.lio.se
Presented at the Twenty-Fourth Ordinary Congress of the Neurootological and Equilibrimetric Society, Haifa, Israel, April 6–10, 1997.

face would be oriented in front of them. This angle, relative to true horizontal, is an estimate of subjective tilt.

The sensation of tilt depends on information from both otolith organs. However, the side directed outward in the rotation makes the greatest contribution to the response, whereas the opposite side contributes to only a minor extent. Thus, the response can be considered an estimate of the function of the otolith organ in the laterally directed ear. In subjects in whom one labyrinth has been surgically removed, there has been a long-term finding corresponding to a response from the opposite ear of approximately 7 degrees [1]. Normal subjects and some subjects in whom a peripheral vestibular deficit has been identified have previously been investigated [2]. We have proposed a side difference index of 25% as the limit of normality for the test.

MATERIALS AND METHODS

Investigated in this study were 25 subjects (10 women, 15 men) aged 34–73 years (mean, 59 years), suffering from unilateral Meniere's disease and treated conservatively with regimen diuretics and, in some cases, occasional sedatives.

Standard pure-tone audiometry was performed. Pure-tone threshold was taken as the average of thresholds on 0.5, 1.0, and 2.0 kHz. Bithermal (30° and 44°C), binaural caloric irrigation was performed in darkness and was recorded by electronystagmography. The caloric side difference according to Jongkees' formula was calculated; it is considered normal if less than 20%.

For the otolith test, we used a low-torque rotatory chair in which the subject was seated 100 cm from the vertical rotational axis facing the direction of the constant rotation. The chair could be turned 180 degrees for change of rotation direction. Rotation was begun with an angular acceleration of 10 degrees/sec², until angular velocity of 120 degrees/sec was reached. On the basis of these parameters, the theoretical tilt angle was 24.1 degrees. Deceleration was performed accordingly. The room was totally dark. Approximately 60 cm in front of the subject's eyes, a dim light-emitting diode bar was turned on for the subject to adjust (via a three-button keyboard held in the hands) to the direction thought to be that of a water surface. By definition, a perceived tilt outward (i.e., a "correct" response) results in a positive angle (regardless of rotation direction). Software in an IBM-compatible computer administered the test via an operator and read the set angles of the light-emitting diode bar. The subject was strapped firmly to the chair to minimize body movements, and the head was held in an adjustable frame.

With the subject firmly attached to the chair and the room totally darkened, eight measurements of per-

ceived horizontal were performed before rotation was started. The mean and standard deviation were computed. The chair was started in one direction and, after 1 minute of constant speed, another eight measurements were performed. The chair was decelerated and, after 1 minute of complete stop, another eight measurements were conducted. After another 5–6 minutes of standstill, the last measurement of perceived horizontal was performed another eight times. The operator then walked into the room and turned on the lights when the chair was turned 180 degrees, so as to conduct another identical series of measurements using the other rotation direction.

As a measure of the effect of the laterally directed linear acceleration, each subject's difference in perceived angle during rotation compared to the value prior to the start of rotation was computed and denoted eccentric rotational tilt response (ERTR). The normal ERTR value of a healthy ear is 19.6 ± 6.3 degrees [2]. As a measure of side difference in the ERTR, a laterality index was computed as $ERTR_{right} - ERTR_{left}$ divided by their sum. This index (expressed as a percentage, omitting the sign) for normal subjects is logarithmically skewed with a mean of 12.6%, median of 8.5%, seventy-fifth percentile of 19.5%, and upper fifth percentile of 25%.

The correlation coefficient between variables was computed, and an ANOVA of the linear regression evaluated the possible dependence between variables.

RESULTS

The mean hearing loss in the diseased ear was 54.6 dB (SD, 18.7 dB). The caloric side difference on average was 28.5% (SD, 22.2%) and, in 15 cases, it was pathological compared to a normal population (i.e., >20%). The laterality index of the ERTR in 11 cases was toward the opposite ear (so-called paradoxical reaction) and, in 14 cases, was directed toward the diseased ear. The value was outside the normal limit of 25% in four paradoxical cases, compared to three "correctly" directed cases. No statistically significant correlation was noted among any of the variables: pure-tone threshold in the audiogram, caloric side difference, and laterality index in ERTR.

DISCUSSION

No relationship among the three studied variables was found in this study of conservatively treated Meniere's patients. This is partly in agreement with the knowledge that Meniere's patients often exhibit different degrees

of functional loss regarding the audiometry compared to the caloric reaction. Obviously, the otolith function does not follow the path of any of the two other variables to any measurable extent. It would, however, be of great value to study the relationship between the otolith and caloric reaction deficits caused by gentamicin treatment [3]. Probably, gentamicin not only destroys the semicircular canal function (as shown in the caloric test) but, to some degree, the otolith function. Such a study currently is under way in our laboratory.

Several methods have been used to test the otolith organs: off-vertical axis rotation, pitch-and-roll rotation, ocular tilt, linear acceleration, and static tilt estimation [4–8]. With eccentric rotation, the otolithic organs are stimulated with a constant linear acceleration without any stimulation of the semicircular canals. The perceived horizontal may be influenced also by proprioceptive cues from the firm attachment of body and head in the rotatory chair.

We propose that the functional impact of the otoliths in Menière's disease and in other peripheral vestibular diseases is a field of neurootology research that deserves our attention in addition to a study of audiometry and caloric reaction.

REFERENCES

1. Halmagyi GM, Curthoys S, Dai MJ. Diagnosis of unilateral otolith hypofunction. *Neurol Clin* 8:313–329, 1990.
2. Ödkvist LM, Gripmark MA, Larsby B, Ledin T. Subjective horizontal in eccentric rotation influenced by peripheral vestibular lesion. *Acta Otolaryngol* (Stockh) 116:181–184, 1996.
3. Ödkvist LM. Middle ear ototoxic treatment for inner ear disease. *Acta Otolaryngol Suppl* (Stockh) 457:83–86, 1988.
4. Curthoys S, Halmagyi GM, Dai MJ. The acute effects of unilateral vestibular neurectomy on sensory and motor tests of human otolithic function. *Acta Otolaryngol Suppl* (Stockh) 481:5–10, 1991.
5. Friedmann G. The judgement of the visual vertical and horizontal with peripheral and central vestibular lesions. *Brain* 93:313–328, 1970.
6. Friedmann G. The influence of unilateral labyrinthectomy on orientation in space. *Acta Otolaryngol* (Stockh) 71:289–298, 1971.
7. Furman JMR, Schor RH, Schumann TL. Off-vertical axis rotation: a test of the otolith ocular reflex. *Ann Otol Rhinol Laryngol* 101:643–650, 1992.
8. Tribukait A, Bergenius J, Brantberg K. The subjective visual horizontal for different body tilts in the roll plane: characterization of normal subjects. *Brain Res Bull* 40:375–381, 1996.