Introduction

Vertigo is one of the most unpleasant and frightening feeling in human’s life. The otoneurologist has an important role in the evaluation of the dizzy patient. Neurootology- as a border-line problem of the otology and neurology-means the examination and treatment of the cochleovestibular diseases.

The definition of the vertigo is not easy. The otoneurologist has to treat dizziness of vestibular origin. He has to diagnose various types of vestibular dysfunction, and has to differentiate between central or peripheral vestibular lesion. During the course of balance system disease the vestibular symptoms are variable and fluctuating. In an optional point of this process the neurootologist performs the vestibular examination, so the symptoms depend on the staging of the disease and can be diversified. Diagnosis vascular lesions of the vestibular system is not easy, because there is not any specific "vascular" symptom of the vestibular lesion.

The whole cochleovestibular system’s blood supply comes from the vertebrobasilar system. Although the main vessels of the brainstem and Willis circle can be seen in angiograms, arteries of the cochleovestibular system can be observed neither with the transcranial Doppler sonography, nor with magnetic resonance angiogram. When vascular origin of the cochleovestibular dysfunction is mentioned, diagnosis is based on exclusion of other diseases, like Meniere’s disease, benign paroxysmal positional vertigo, vestibular schwannoma, or central vestibular lesions like multiple sclerosis. Vertebrobasilar ischaemia can be responsible for a wide range of central and peripheral vestibular syndromes. Ischaemia sometimes produces a combination of central and peripheral vestibular symptoms. The correct differential diagnosis of these syndromes is very important, but is not easy at all.

The small vessel diseases and atherosclerosis, causing significant stenosis of the arteries, can
result ischaemic lesion of the vestibular system. Analyzing risk- factors a high incidence of obesity and cervical spondylosis could be seen. Patients can influence the way of life, (diet, smoking, alcohol, drugs). The long lasting hypertension, hyperfibrinogenemia, hypertrigliceridemia, hypercholesterolemia seem to be very important risk factors in vertigo. Diabetes plays only a small role in cochleovestibular dysfunction. Ischemic events in case history, and cerebrovascular disease in family history play a significant role in evaluation of ischemic lesion of balance system. More, than one risk factor means increased risk for ischemic lesion.

Migraine, especially complicated migraine plays a role as a risk factor of vascular disease. The migraine is now known to be a well defined symptom complex. Two different types of vertigo were found in patients with vertiginous migraine. In basilar migraine patients complained of a true rotatory vertigo during the headache, which lasted from a few hours to a day. In the headache free period the patient felt normal, and had no dizziness or motion sickness. In vestibular migraine patients experienced rotatory vertiginous attack that lasted a few minutes before headaches began. Most patients felt persistent unsteadiness in the headache free period. While vestibular migraine patients resemble to neurotic patients, the complaints of the basilar migraine patients seem to be vertebrobasilar insufficiency.

Basilar migraine is not always benign disease, sometimes severe episodes of stroke occur. Experimental studies show, that vascular lesion due to vertebral artery occlusion is more severe in brainstem, than in cochlea. In experimental AICA occlusion the blood flow of the cochlear and vestibular nuclei is impaired, compared to the normal control, and to the healthy (unobstructed) side. Due to AICA occlusion the vestibular nuclei lost one third of their blood flow, while cochlear nuclei lost half of their blood flow.

Partial blood flow of CO₂ influences the blood flow, causing hypercapnia, dilatating vessels. Vestibular examination in cerebrovascular diseases is very difficult not only because of the variable symptoms, but because of the different examination methods.

The registration of the vestibulo-ocular reflex is very important. Every otoneurological laboratory uses provocative tests for eliciting nystagmus. Eye movement examination can be performed by smooth pursuit system examination, or by optokinetic stimulation. The other important examination is the labyrinthine eye movements examination by using caloric irrigation for provoking endolympha flow. The caloric test is one of the most important method for the otoneurologists.

Caloric nystagmus can be provoked with warming or cooling the endolymph through the
external ear canal. Caloric test can be performed with water or air. Several methods of caloric tests are known. Most computer analysis softwares give us the slow phase velocity of the nystagmus, which is considered the most characteristic value of the nystagmus. The normal values of the slow phase velocity depend on the examination methods. Normally the amplitude, frequency and duration of the provoked nystagmus after the two cold and warm water irrigation is almost equal. The normal difference which can be accepted is 15-25%.

In so-called canal paresis (or caloric weakness) the labyrinth responsiveness for the warm and cool irrigation decreased unilaterally, while in directional preponderance the nystagmus beating to one side is more intensive than towards other side. Caloric weakness is characteristic for peripheral lesions, while directional preponderance can be seen frequently in central vestibular lesions.

Since 1989 in the Otolaryngology Department of Semmelweis University electronystagmography is used in examination of the patients with vertigo, and since 1996 we have possibility for using computer-based nystagmograph system.

**Objects**

I wanted to clarify the helpfulness of otoneurological examinations in the diagnostic procedure of cerebrovascular diseases.

1. Because the method of electronystagmography is available for the monitoring changes of the vestibular system, vestibular changes were registered in patients with cochlear implant due to bilateral deafness. Cochlear implantation is a worldwide accepted method for rehabilitation patients with total deafness. The cochlear implant is an electronic device, which can stimulate the hair cells of inner ear, or cochlear nerve, with converting the sounds to electric stimuli. The aim of my investigation was to know, how the cochlear implantation affects on vestibular responsiveness on the operated and contralateral side.

2. Which are the risk factors predisposing to vertigo?. Are these factors the same as the general risk factors of cerebrovascular diseases, or other diseases or factors could be recognized? How do the climatic factors, the way of life, and diet affect the vertigo?

3. As vertiginous migraine could be a risk factor of cerebrovascular diseases, I investigated the vestibular system abnormalities in patients with migraine.

4. I examined the patients to investigate the vestibular disorders, electronystagmographic abnormalities in cerebrovascular diseases. Detailed evaluation of patients was performed
to verify the cerebrovascular disease.

5. How do the vestibular symptoms fluctuate during the course of vascular disease? I wanted to answer, whether any regularity could be seen in the vestibular changes?

6. It is well known, that hypercapnia can cause vasodilatation, and under hypercapnia the cerebral blood flow is increasing. My aim was to investigate, how hypercapnia can affect the vestibular system function. I looked for the investigation method of provoking hypercapnia for eliciting nystagmus changes, and I tried to use it in clinical practice.

**Patients and methods**

Patients underwent detailed oto-rhino-laryngological, neurological, audiological and otoneurological examination. They were checked for spontaneous nystagmus and Romberg, Barany, Babinski-Weil tests for statokinetic function were performed. Spontaneous nystagmus was observed using Frenzel glasses and since 1989 by electronystagmography as well. The bithermal caloric test was performed using a computer-based ENG system (ICS Chartr® ENG). The duration of the irrigation and the air temperature can be preset. The irrigation time is 40 seconds, the temperature of warm air is 50 °C, while that of the cool air is 25 °C, the flow rate is 5 l/min.

The total duration of the cochleovestibular examination is about 1.5-2 hours, the nystagmography is about one hour long.

We examined the effects of cochlear implantation on vestibular system in patients with total deafness. In these patients either the preoperative or the postoperative electronystagmography was performed by computer based ENG.

Patients with vertiginous migraine were examined to evaluate, what kind of changes can be seen in vestibular system due to migraine. With the exception of one patient, who had constant vomitus, patients underwent complete otoneurological examination during the migrainous attack. The electronystagmographic examinations were repeated in attack-free period.

The age of the selected cerebrovascular patient-group was planned to be between 45-64 years of age. The reason of this planned range was the following: up to 45 years the cerebrovascular disease is rare, and we wanted to concentrate on the cerebrovascular diseases. On the other hand, in patients older than 65 years of age old presbystasis (age-related vertiginous symptoms) occurred frequently, and we wanted to exclude this as a reason
of vertigo. In the Neurootological Department of Semmelweis University we examined more than 2000 vertiginous patients in 1999. Ninety-nine patients were 45-64 years old, in most of them several reasons of vertigo were diagnosed, e.g. Meniere’s disease, paroxysmal positional vertigo, vestibular schwannoma, chronic otitis media, or other peripheral or central vestibulopathies.

In the last 3 years we examined 65 patients, in whom a cerebrovascular disease of vascular origin was diagnosed. The data of these 65 vertiginous patients with or without hearing loss were examined, where the cause of vertigo and hearing loss was diagnosed to be of vascular origin. The patients had occipital headache, rotatory vertigo after head movement, drop attacks, sometimes transient diplopia and sensorineural hearing loss. Patients having with chronic otitis media, other middle ear disease or previous ear surgery were excluded from the study.

The examination began with detailed case-history and routine oto-rhino-laryngological and neurological examinations. Complete neurootological and audiological examination, Doppler sonography, magnetic resonance imaging and magnetic resonance angiography were performed. Written informed consent to participate in the examinations was obtained from each patient.

Cochleovestibular function of all the patients was examined by separate audiological and vestibular function tests. Cochlear function tests included pure tone audiometry, acoustic reflex threshold and decay and brainstem evoked response audiometry. Vestibular tests involved statokinetic tests (Romberg, Barany and Babinski-Weil tests), spontaneous nystagmus with ENG registration, positional and positioning nystagmus with Frenzel glasses. The smooth pursuit eye movement tests and bithermal caloric test were carried out by computer-based ENG system (ICS Chartr ENG® system, irrigation parameters: air temperature is 50 °C and 25 °C, time is 40 seconds, air flow is 5 liter/min.).

ABRs were measured in every patient. In all the patients Doppler sonography of the carotid and vertebral artery was performed. The carotid and vertebral arteries were non-invasively evaluated by a color-coded duplex scanner. Magnetic resonance imaging and magnetic resonance angiography were performed in order to exclude space occupying lesions and to visualize vessels of the Willis circle and vertebrobasilar artery.

In 20 patients the nystagmus changes due to hypercapnia were examined. In order to provoke hypercapnia the patients were rebreathing their own air in a 3-minute-long period. The nystagmus was registered by computer-based electronystagmography before, during and after
the hypercapnia.

**Results**

Electronystagmography is useful method for monitoring of changes in vestibular responsiveness. Due to the atraumatic surgical technique during insertion of the cochlear implant electrode no impairment of vestibular responsiveness of the operated ear could be diagnosed in most of our cases. In few patients improvement of the vestibular function could be observed not only in the operated ear but also in the contralateral one. The increase of slow phase velocity values of caloric nystagmus on the contralateral side means that the caloric responsiveness improved in cochlear implant patients. The reason of the improvement is not clear. It may have been caused by presently obscure trophic influence on the vestibular system. The mastoidectomy, being the part of the cochlear implantation can change the responsiveness of the horizontal canal to caloric stimuli on the operated ear, but not on the contralateral ear. The role of brainstem function in the improvement of the contralateral caloric response is not clear yet. The other possibility is the influence of hearing impulses affecting the labyrinth. The changes of the contralateral caloric response show the presently obscure role of the brainstem in caloric test results.

Vertebrobasilar ischaemia can often be responsible for a wide range of central and peripheral vestibular syndromes. Ischaemia will sometimes produce a combination of central and peripheral vestibular symptoms. Since arteries of the cochleovestibular system cannot be directly visualized, we have to deduce to the vascular cochleovestibular disease from the vascular risk factors and the vascular lesion of other territories.

In our patients wide range of vascular disorders could be observed (multiple infarctions, leukoaraiosis, atrophy, vertebral artery occlusion, megadolichobasilar artery, or multiple variants of vessels). The brainstem audiometry and vestibular examination showed several lesions of the brainstem function and labyrinthine function (central and peripheral, and combined vestibular lesion). In most of the patients multiple risk factors of cerebrovascular disorder (obesity, hypertension, hypercholesterolaemia, small joint disease of the cervical vertebrae) could be observed.

Cochleovestibular system dysfunction can be considered to be of vascular origin if the examinations exclude other diseases, if the patients have vascular risk factors and/or if other territories of brain accessible for imaging methods show vascular disorders.
Otoneurological examination, especially with electonystagmographic registration shows changes in vestibular function during the cerebrovascular disease. Symptoms are variable and fluctuating; while harmonic syndrome is characteristic in peripheral lesions, disharmonic syndrome can be observed frequently in central lesions. The severity of the symptoms are also variable, beside severe gait disturbances there is no vertigo, or with severe vertigo and feeling unsteadiness the patients can walk straight with closed eyes. Consequently, in these cases objective examination of the balance system is very useful.

Prior to examination of patients with cerebrovascular disease vestibular function was examined in several diseases: in migraine and in bilateral deafness.

I worked out the method of vestibular examination by computer based ENG system, and the possibilities of air caloric irrigation in cases of previously operated ear and tympanic membrane perforation. Air caloric irrigation is a safe and useful method in the patients’ examination.

The ratio of the cerebrovascular diseases in vertiginous patients is much more than we think on the basis of other statistics of literature. Prior to big vascular occlusions very often complaints of vertigo, headache, balance-system disorders can be observed. If these disorders are recognized in time, we might prevent big stroke of the patients. Unexpected result of the study was the high ratio of the cerebrovascular disorders and small ratio of peripheral vestibular disorders among the vertiginous patients. The risk factors of vertigo were resembling of risk factors of cerebrovascular diseases, but the ratio of smokers and diabetic patients were smaller. However, the ratio of cervical spondylosis were higher. Hypertension, hypercholesterolemia, atherosclerosis, migraine, cervical spondylosis seem to be the main risk factors in the etiology of vertiginous diseases.

Vascular lesion of the vestibular system can cause either peripheral or central vestibular lesion. Otoneurological examination can help to differentiate them.

Reactions of brainstem nuclei for the hypercapnia could be different due to changes of brainstem autoregulation. Due to blood flow changes frequency of spontaneous nystagmus and slow phase velocity is increasing, sometimes the direction of nystagmus changed.

Presumably due to Willis circle asymmetry, there is an increase in different degree in the brainstem blood flow, and especially in the vestibular nuclei, and this fact can cause changes in nystagmus parameters. The examination of nystagmus changes due to hypercapnia could be a new method for evaluation of brainstem vestibular nuclei function in the hands of otoneurologist.
The changes in balance system could be followed by the help of vestibular examinations. Patients with balance system disorders need continuous care and controll. The vertiginous patients with vascular risk factors have to be considered as a cerebrovascular patients, as sudden blindness due to ophthalmic artery occlusion is considered to be a transient ischemic attack.

One of the main symptoms of vertebrobasilar insufficiency is vertigo and sometimes hearing loss. If we cannot find other otological and neurological disease, the vertigo and hearing loss have to be considered as TIA, and we must treat it as TIA of the vertebrobasilar territory.

While with ENG examination we have to diagnose brainstem function disturbances, the otoneurologist has a considerable role in diagnostic procedure, and has to cooperate with the neurologist to prevent big strokes of vertebrobasilar territory.

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